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ABSTRACT

Many educators feel that elementary school science programs should concentrate on phenomena and concepts that are literally tangible. This document serves as the teaching manual which accompanies the Capsela modular system of manipulative and motorized models. The experiments in the manual are intended to provide a structured approach to using the Capsela system as a teaching tool. The manual contains sections on: (1) making Capsela a part of the science program; (2) using Capsela in the science curriculum; (3) lesson skill development; (4) Capsela gear capsule descriptions; (5) how to get started; (6) classroom management suggestions; (7) creating a movement-thinking learning environment; (8) creativity with a purpose; and (9) using Capsela at home. A major portion of the document contains descriptions of 25 lessons dealing with the concepts of force, work, energy, momentum, machines, electricity, fluids, Archimedes' Principle and Newton's Third Law. (TW)

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CAPSELA SCIENTIFIC

HANDS-ON PHYSICAL SCIENCE CURRICULUM FOR GRADES 3-9

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Manufactured By: Play-Jour International Ltd.
New World Office Building
(East Wing), Room 914
21 Salisbury Road
Tsimshatsui, Kowloon, Hong Kong

DR. CLIFFORD SWARTZ'S STATEMENT

Elementary school science should concentrate on phenomena and concepts that are literally tangible. The students should personally experience the action of forces: they should control small motors and view energy change forms; they should measure the rise of water in a container as an object is submerged. Just reading descriptions of these phenomena, or looking at pictures, does not produce science learning that is retained in later years.

Capsela provides tangible experiences in a format that children find challenging and fun as they follow the diagrams and build innovative motorized models. Capsela is unique, however, in providing a modular system where many principles of science and engineering are dramatically visible. The capsules are ready-made for the modern operational approach to the design of processes and machines. There are energy storage capsules, energy transformation devices (motors, lamps), and torque and speed converters (gear capsules).

The experiments in this manual provide a structured approach to using Capsela as a teaching tool. In addition, the principles that are learned enable the student to use Capsela in sophisticated and powerful ways to solve problems. Given the need to produce a model that will perform certain functions (e.g. low speed, high torque, circular motion), the student can select components according to their previous measured properties, and assemble them in a logical way.

The phenomena and principles that your students will experience in these lessons involve force, work, energy, momentum, machines, electricity, fluids; Archimedes' Principle and Newton's Third Law. The material can be studied over a wide range of age and ability levels. I have watched both eight year olds and adults assemble Capsela models and explore the processes in useful but different ways. The classroom teacher can adapt the lesson sequence to different grade levels by varying the lesson time, the extent of group participation, and the nature of the quantitative work involved. For instance, in Lesson 8 (Leverage) third graders can learn through experience how to adjust lever arms to exert maximum force, sixth graders can do arithmetic to show that the work put into a lever equals the work output, and the ninth grader can do quantitative comparisons of the energy loss in more complicated machines. Furthermore, the Capsela models are fascinating enough that even if a student has worked with them at home or in an earlier grade, the challenge of more sophisticated study remains.

There is a lot of interesting and useful science to be learned with the Capsela system. There is also a lot of enjoyment in creating the models and solving design problems. The learning and enjoyment enhance each other. We hope that your students will have fun doing these lessons and that because they are having fun they will be led to creative learning.

EDUCATOR MADELEINE FRIEDMAN'S COMMENTS "TEACHER TO TEACHER"

USING CAPSELA SCIENTIFIC AS AN ESSENTIAL PART OF YOUR SCIENCE CURRICULUM

WHY USE CAPSELA IN YOUR CLASSROOM?

Children like Capsela. The components are easy for young fingers to manipulate. The sets are durable and expandable. Capsela looks like a toy -- but it is much, much more.

CAPSELA IS AN EDUCATIONAL PRODUCT THAT CHALLENGES YOUNG MINDS WITH A HANDS-ON EXPERIENCE, CREATIVITY WITH A PURPOSE, AND THE DEVELOPMENT OF A NEW VOCABULARY

The children think with their eyes and fingers. The world of mechanics and electronics can be introduced in an active, participatory setting. Discovery is the key word in the Capsela Scientific activities, and discovery sparks interest, motivation, and imagination.

CAPSELA IS A BUSY TEACHER'S BLESSING

You don't have to scrounge around for bits of wire. You don't have to dismantle clocks and broken toys in order to show your students what a circuit is or how simple machines operate in the real world.

CAPSELA WILL HELP GET YOUR STUDENTS "HOOKED" ON SCIENCE

The Capsela Scientific Manual is rather unique in that it covers a broad range of topics appropriate for the third through ninth grade level. Physical science will come alive when you have Capsela to back up the concepts your students are reading about. They can experiment intelligently with different gear and circuit combinations, and can see exactly how their creations function. Capsela's use in demonstrating extended applications in force, work, energy, momentum, machines, electricity, fluids: Archimedes' Principle and Newton's Third Law make it an ideal teaching tool throughout coverage of your total science curriculum.

CAPSELA SCIENTIFIC
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INTRODUCTION

MAKE CAPSELA A PART OF YOUR SCIENCE PROGRAM
Open your Capsela Scientific set and look at it carefully. You will see a vast array of devices for storing and transforming energy. These devices are literally transparent, allowing the student to see and control mechanical and electrical processes.

Capsela Scientific is directed towards educators of the third through ninth grades.

All the lessons can be adapted to the specific grade level by varying the lesson time, the extent of group participation and the nature of the quantitative work involved. Conceptually the same material can be understood by third graders while still challenging students through the ninth grade level.

When you present Capsela Scientific within a structured curriculum format, you are giving your students an opportunity to experience their textbook and tradebook science concepts as never before.

1. Start your class off with the activities described in this manual. You will notice that each lesson consists of three sections:
   - A. The Teacher's Overview
   - B. The Teacher's Notes
   - C. The Student Hand-Out Masters (Answers are listed in Appendix 1)
2. The lessons can be taught independently or grouped. However, it is best if the lessons are taught sequentially. At times one lesson builds on the preceding ones or introduces topics that will be used later.
3. Use your science textbooks and tradebooks as a valuable resource in defining and explaining the concepts under study.
4. Now let your students discover their own unique combinations and applications of the original concepts.
5. We would welcome any comments or discoveries that you may make after using our program.

Creative teaching is at your fingertips. Give your students the gift of discovery learning -- with Capsela.

TO INSURE THAT YOU RECEIVE UPDATED PROJECTS AND ACCESSORY INFORMATION PLEASE BE SURE TO SEND IN YOUR WARRANTY REGISTRATION CARD NOW.

CAPSELA IN THE SCIENCE CURRICULUM

Capsela can help your students experience the following scientific concepts:

Force: A force is a push or a pull. Forces can be felt or exerted with fingers, and can be measured by stretching spring scales.

Work: To perform work you must exert a force through a distance. Work is something you do or a machine does.

Energy: Work can be transformed into stored energy. Various forms of energy can be transformed into each other -- electrical, chemical, gravitational, motion, heat.

Momentum: The product of mass and velocity.

Machines: Levers, inclined planes, wheel-and-axles, and pulleys are simple machines. Machines transform work or energy from one form to another. Machines allow an exchange of greater force output for shorter distances traveled, or less force for greater distance. Similarly, they allow greater torque at smaller rotational speed, or smaller torque at higher speed. Machines can also make the direction of the output force or torque different from the input force or torque. Energy output from a machine is always equal to or less than the energy input.

Electricity: Electricity can flow only through a closed path (or circuit). Electricity can flow in one direction or the other in a wire, depending on the way the ends of the wire are connected to the battery. The direction of the electric current in an ordinary light bulb makes no difference in the amount of light produced. However, some motors will reverse their direction if the current is reversed. Two batteries in series provide more voltage and thus more energy than one single cell.

Fluids: Archimedes' Principle: An object in water is buoyed (or pushed up) by a force equal to the weight of the water displaced. Therefore, an object will float if it weighs less than water having the same volume.

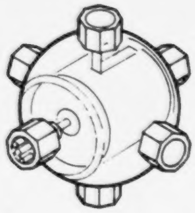
Newton's Third Law: If one object exerts a force on a second one, the second one exerts an equal and opposite force on the first one.

LESSONS' SKILL DEVELOPMENT CHART

LESSON TITLE	PRIMARY CONTENT PROCESSES							
	Experimentation	Drawing Conclusions	Oral & Written Communication	Making Comparisons	Use of Models & Diagrams	Forming & Understanding Definitions	Application of Previous Knowledge	Creating Plans to Solve Problems
1. Mechanical Energy, Work & Energy Storage	*	*	*					
2. Electrical Energy, Circuits, Chemical and Motion Energy		*	*		*			
3. Electric Circuits, Polarity, Energy Transfer	*	*	*	*	*			
4. Speed Reduction, Gear Transformation of Speed and Torque	*	*	*	*	*	*	*	
5. Energy & Speed Transformation: The Racing Car	*				*			
6. Complex Machine: The Revolving Tower	*	*	*				*	
7. Force	*	*	*					*
8. Leverage: The Lever With a Capsela Vehicle	*	*	*	*	*			
9. Inclined Plane & Measurement: Tractor	*		*			*		
10. Finding The Lost Energy, Friction & Heat Energy	*	*	*	*	*	*	*	
11. Series & Electric Circuits & Energy Sources	*		*		*			
12. Electric Circuits & Blinking Light Behavior	*		*	*	*		*	
13. Energy Transformation: The Blinkmobile	*	*	*					*
14. Circuitry, Energy: The Robot	*		*	*				
15. Buoyancy & Fluid Displacement	*	*	*			*		
16. Buoyancy, Equal & Opposite Forces: Propeller Boat	*	*	*				*	
17. Pumping Water: The Water Pump	*	*	*					*
18. Equal & Opposite Forces: The Hydrojet	*	*	*		*			*
19. Equal & Opposite Forces, Different Medium: Motor Boat	*	*	*					
20. Equal & Opposite Forces, Different Speed: Ferry Boat	*	*	*	*				
21. Wheel-and-Axle: The Hoist	*			*	*	*	*	
22. Chain Drive, Chain-Linked Gears, The Worm Gear: Mini Cycle	*	*	*	*		*		
23. Shifting Gears & The Clutch Capsule: The Crash Car	*	*	*	*	*	*		
24. Vacuum: The Vacuum Cleaner	*		*					
25. Circuitry, Forces: The Propeller Car	*		*					
Capsela Olympics	*	*	*	*	*	*	*	*

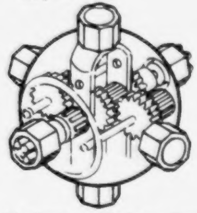
CAPSELA GEAR CAPSULE DESCRIPTION

1. Motor Capsule



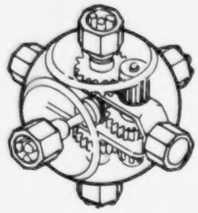
- Power Source to motorize all models
- Activated by AA battery
- 960 RPM Speed

2. Speed Reduction Capsule



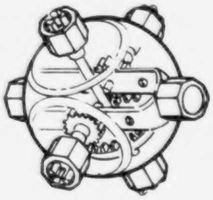
- Reduces Motor Speed (Ratio 23:1) but increases the torque or turning power

3. Worm Gear Capsule



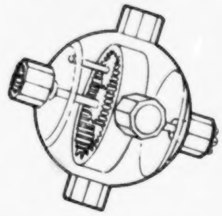
- Combines function of speed reduction and crown wheel capsules into a single unit. Decreases RPM ratio to 48:1.

4. Crown Wheel Capsule



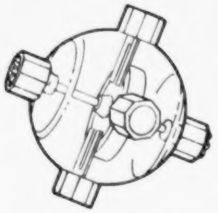
- Changes direction of motive drive through a 90 degree angle. Decreases the RPM ratio 2:1

5. Internal Gear Capsule



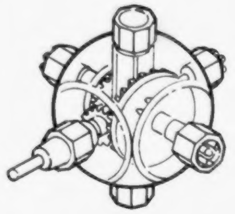
- Changes Shaft Speed (increases or decreases RPM ratio 3:1) without changing direction of motive drive

6. Rotary Switch Capsule



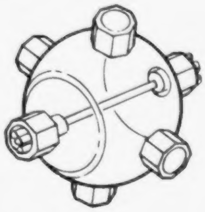
- As shaft turns switch is opened and closed activating blinking light function

7. Clutch Capsule



- Designed to engage or disengage motor drive allowing two separate individual actions on same model
- Double clutching mechanism

8. Transmission Capsule



- Extends gear action without changing the connecting gear motive force

Spare capsules and accessories (refer to Parts List in Back Sleeve) can be obtained from:

Play-Jour Inc.
200 Fifth Avenue, Suite 1024
New York, NY 10010

HOW TO GET STARTED

1. Examine the components in the Capsela Scientific Set.
2. You may want to assemble some of the various components like the impellers, chains, or put the rubber tires on the wheels.
3. Insert AA batteries in both battery cases.
4. Remove the design manual (in Back Sleeve) if you want your students to use it to explore other construction possibilities.
5. Check the lamp to make sure that the lightbulb is secure; it may loosen up in transit or with repeated handling. Carefully snap off the red plastic cover and screw the bulb back into place.
6. Remove the outer cardboard box; use the styrofoam tray for neat and easy storage and mobility. Or, a Capsela Storage Bag made of heavy gauge see-through vinyl is available (refer to Back Sleeve).
7. If at all possible, put the models together yourself so that you will find it easier to help your students when they ask you questions. (Construction time rarely exceeds 10 minutes.)*

*When time does not permit you to build the demonstration models, assign one or two children in your class to be monitors in charge of building the demonstration models before each lesson. These students can also be in charge of disassembling the structures before the kit is presented at the learning station, and they can help others "debug" their creations during Capsela learning center activities.

CLASSROOM MANAGEMENT SUGGESTIONS

THE LEARNING CENTER APPROACH

Capsela construction activities can be easily presented within a learning center environment.

A. Introduce the Center and the concepts to your class as a whole.

B. Rotate your children in groups of 3 to 5 through the activity portion of the lesson.

C. Evaluate and record each student's progress.

D. Allow additional "free time" for your students to creatively investigate Capsela's endless options.

CAPSELA CAPTAINS

When several children are working together at your Capsela learning station, assign one student to act as Capsela Captain. The Captain can be in charge of disassembling the group's model after completion of an activity; he or she can also be responsible for replacing the components and cleaning up the Center for the next group.

STORAGE OF SMALL COMPONENTS

Plastic sandwich bags can be used to replace original plastic bags that have become torn. As for storage of all the Capsela parts, refer to Back Sleeve for information on the Capsela Storage Bag.

GROUP DISCUSSIONS

After the entire class has rotated through an activity, hold a group discussion to give your students a chance to verbalize what they experienced and to ask questions that came up as they worked at the Center.

THE VALUE OF MOVEMENT THINKING

Try using your Capsela activities as preliminary introductions to material covered in the textbook. See how it enriches their total learning experience.

CREATING A MOVEMENT-THINKING LEARNING ENVIRONMENT

A SPECIAL ATTITUDE TOWARD LEARNING

The learning atmosphere surrounding Capsela discovery experiences is different from that governing the usual textbook/ worksheet presentations. Let the following perspectives guide you in creating a learning environment that complements the Capsela movement activities.

THERE IS NO SUBSTITUTE FOR EXPERIENCE

Adults as well as children sometimes have difficulty following an oral presentation. What your students have missed in your oral explanation will need to be re-discovered if they are to experience success in their Center activities. The movement activities in Capsela will give your students another chance to learn the concepts you are trying to impart.

"DEBUGGING" IS NOT FOR COMPUTERS ONLY

In the world of movement thinking, there is nothing wrong if your students encounter obstacles on the road to concept formation. Luckily, your students are not bound to a set of answers written on a ditto or in a workbook. When a model does not work as expected, some visual study along with manual adjustments may be necessary to remedy the situation. Look at this as a "debugging" process. Encourage your children to discover their own miscalculations. Let them know you are confident that they will eventually solve their problems. When they have debugged their own errors, they will have taken responsibility for their own learning. Watch their confidence grow!

MISTAKES ARE OPPORTUNITIES FOR CONCEPTUAL GROWTH

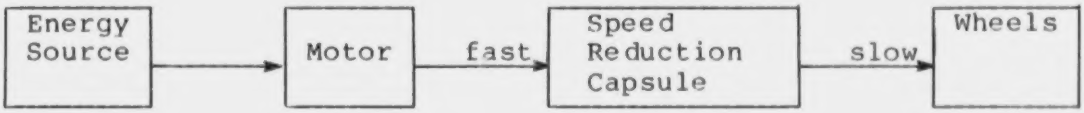
A "mistake" can lead to new and exciting discoveries. An "improperly" chosen component may reveal previously unseen possibilities. A capsule "wrongly" placed might raise questions requiring library research to clarify. If you regard "mistakes" as learning opportunities rather than learning obstacles, your Capsela activities will add an inspiring, creative dimension to your teaching day.

CREATIVITY WITH A PURPOSE

Sometimes it is fun just to explore new possibilities -- to take a learning experience as far as it will go. Often it is amidst unbridled creative exploration that exciting discoveries are made.

At appropriate intervals, you may choose to allow your students to experiment with other structures pictured in the Design Manual. As time goes on, many children will even choose to create models of their own design.

To maximize the educational value of these explorations, encourage your "explorers" to display their creations to the class. Ask them to explain what they made and how it works in terms of a logical approach to their design problem. What is the energy source? What kind of energy is it? How is that energy transformed to some other kind of energy? Does the motor turn fast or slow? What is the desired output? Motion? Fast or slow? Light? Steady or flashing? These questions and answers can be recorded on the blackboard.



The learning process is most effective when it requires a combination of hands-on experience and logical description.

WHAT IF YOUR STUDENTS ALREADY HAVE CAPSELA AT HOME?

THEY BUILD WITH CAPSELA, BUT DO THEY THINK WITH CAPSELA?

Many of your students will tell you that they have Capsela sets at home and that they already know how to build with Capsela, but do they know how to THINK with Capsela?

YOUR PURPOSE IS TO TEACH SCIENCE TO YOUR STUDENTS USING CAPSELA AS A MEANINGFUL EXTENSION OF THE CONCEPTS PRESENTED IN THEIR TEXTBOOKS

Your purpose in the classroom is not to teach the children to build. Building is merely a means to an end.

Chances are, your Capsela owners are in need of additional explanations regarding the purpose of each capsule. Most students with Capsela sets at home are anxious to understand what specific capsules do and why they function in certain ways. Classroom instruction increases their understanding of what is happening when they play at home.

ACTIVE THINKING HEIGHTENS STUDENT INTEREST

Once students can apply the purposes of the gears and the circuits, their thinking takes on dimensions not possible with just textbooks alone. When this thinking can be done with eyes and fingers rather than with pencils and words, the children usually take advantage of this opportunity to explore and create with unbounded zeal. Students crave time for creative, open-ended exploration with Capsela. They also crave explanations detailing how the different capsules work, so that they can incorporate this new found knowledge in future experimentation. Balance is the key.

AFTER SPECIFIC CLASSROOM ACTIVITIES WITH CAPSELA SCIENTIFIC, THOSE WHO OWN CAPSELA AT HOME GAIN A DEEPER RESPECT FOR ITS INFINITE POSSIBILITIES

Those who do not yet have a Capsela kit generally want one after they see all the things it can do.

LESSON 1: MECHANICAL ENERGY, WORK AND ENERGY STORAGE

OVERVIEW

The students will use a few of the Capsela components to experience and learn some qualitative facts about energy. This will be the first example of how science learning can be fun. In this lesson the students will not memorize any particular definition of work or energy.

PERFORMANCE OBJECTIVE

Your students will be able to find and connect the Capsela parts to make a propeller whirl, using the twisted rubber band capsule as the energy source. They will be able to demonstrate the need for an energy source and show what happens if the source is disconnected or gets weak. They will be able to describe the effects in terms of work input, energy storage, and transformation (change) to motion energy.

PERFORMANCE STANDARD

Each student should be able to assemble the propeller and rubber band capsule. Each student should describe orally or in writing the energy input, storage, and output sequence.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
10	Oct. Conn.	1	33	Propeller	1
14	Coupler	1	Rubber Band		
15	Coupler Cap	1	Capsule		1

Student Hand-Out Sheet

#1 TEACHERS' NOTES: MECHANICAL ENERGY, WORK AND ENERGY STORAGE

Instead of "whirl," "spin" could be used, but the sound of whirl is so descriptive of its meaning that it would be a shame not to add it to the students' vocabulary.

Neither work nor energy is explicitly defined in this first lesson. However, the students will be experiencing the concepts in terms of their own activities and the everyday use of the words. In later lessons we will approach more formal definitions.

The most basic property of energy is that it can be transformed from one kind to another. In this lesson, human work turns into motion energy (when blowing on the propeller), or into stored mechanical energy (when twisting the rubber band). The stored mechanical energy can then turn into motion (kinetic) energy of the propeller, but eventually the stored energy is gone. However, the air gained motion energy. Finally, everything is quiet and the energy apparently has disappeared. But the air is warmer! The mechanical energy went into heat energy. No need to press this point now, however. We will come back to the concepts of friction and heat in later lessons when the effects will be more noticeable.

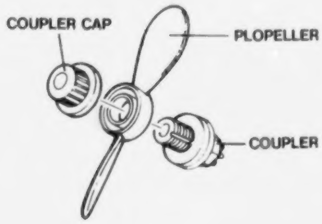
If the children don't know where they got their energy, which went into winding the rubber band or blowing the propeller, ask them how long they could keep going without anything to eat. Where did that energy come from? (The sun.) Where was it stored? (In the food, not the cupboard!)

STUDENT HAND-OUT SHEET #1
MECHANICAL ENERGY, WORK AND ENERGY STORAGE
"GIVE IT A WHIRL!"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
10	Oct. Conn.	1	33	Propeller	1
14	Coupler	1	Rubber Band		
15	Coupler Cap	1	Capsule		1

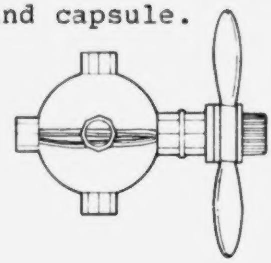
Your Capsela kit has a propeller.



1. Can you make it whirl? ___________
Connect it to a coupler.
Try blowing on it.
Spin it with your hand.
To make it move you had to do some work.
Your work turned into motion energy.

Your work → Propeller's motion energy

Now connect the propeller to the rubber band capsule.



2. Does the propeller spin? ___________

3. Have you given it energy? ___________

Do some work. Wind up the rubber band.

When the rubber band is very twisted your work went into the energy stored in the rubber band.

Your work → Energy stored in rubber band

Now let the propeller spin.

Energy stored in rubber band → Propeller's motion energy

4. When the propeller stops spinning does the rubber band still have stored energy? ___________

5. Where did the energy go? ___________________________________

Your work → Energy stored in rubber band → Propeller's motion energy → ?

6. Where did you get the energy to do your work? _____________
____

LESSON 2: ELECTRIC ENERGY, CIRCUITS, CHEMICAL AND MOTION ENERGY

OVERVIEW
The students will learn to use the battery and electric motor components of Capsela. They will learn to make series connections in an electric circuit of battery and motor. They will extend their experience with stored and motion energy.

PERFORMANCE OBJECTIVE

Your students will be able to find and connect the Capsela parts to power the electric motor with a single battery cell. They will learn to follow a simple wiring diagram. They will handle another kind of device for storing energy (the battery) and another device for transforming energy (the electric motor).

PERFORMANCE STANDARD

Each student should be able to connect the wires from the battery capsule to make the motor run. They should be able to draw a diagram showing battery, wires, and motor. They should describe orally or in writing the energy input, storage, output sequence.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor Capsule	1	23	Wire Leads	2
10	Oct. Conn.	1	33	Propeller	1
14	Coupler	1	New Battery		1
15	Coupler Cap	1	Worn-Out Battery		1
21	Sm. Bat. Case	1			

Student Hand-Out Sheet

#2 TEACHERS' NOTES: ELECTRIC ENERGY, CIRCUITS, CHEMICAL AND MOTION ENERGY

The chemical energy in any electric battery turns into electric energy as the current is produced. The chemical properties of the materials inside the battery change. In the case of a chargeable battery, such as that in a car, the chemical process can be reversed by sending current through the battery in the opposite direction. With ordinary dry cells, the process is irreversible. When the chemical transformations have all taken place, no more current can be generated. The chemical compounds in the battery are different from what they were to begin with.

Technically, a "battery" is a collection of single "cells," usually wired in series so that their voltages add. The usual dry cell produces 1.5 volts. Two in series yield 3 volts. The lead cell in a car storage battery produces 2 volts. Most car batteries consist of six of these cells in series, producing 12 volts. In common parlance, the word "battery" is used even if there is only one cell.

The student may not have to do any work to mix the fresh chemicals in a dry cell and so store energy, but somebody has to do work to produce the chemicals, and somebody has to pay for them. The "conservation of energy" means that what comes out must have gone in, or "you don't get something for nothing."

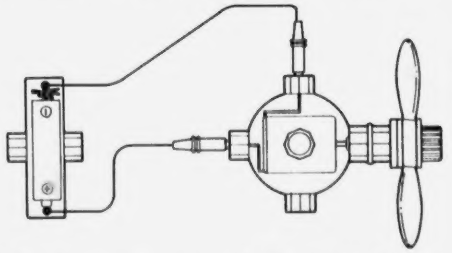
STUDENT HAND-OUT SHEET #2 ELECTRIC ENERGY, CIRCUITS, CHEMICAL AND MOTION ENERGY

MATERIALS: CAPSELA SCIENTIFIC

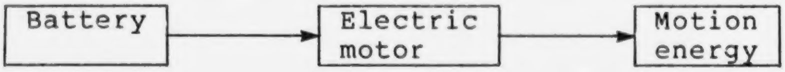
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor Capsule	1	23	Wire Leads	2
10	Oct. Conn.	1	33	Propeller	1
14	Coupler	1		New Battery	1
15	Coupler Cap	1		Worn-Out Battery	1
21	Sm. Bat. Case	1			

Let's find out if you can store energy without doing any work.

Connect the wire leads to the new battery. Connect the coupler to the white gear of the motor along with the propeller.



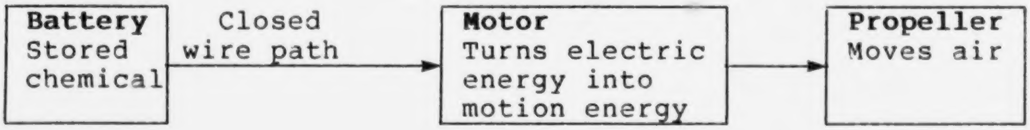
Look! You get motion energy without doing any work! (Or do you?)


Battery
Electric motor
Motion energy

To find out where the energy comes from try using an old battery.

1. Does much energy come out? ____________________

   A battery stores chemical energy. The chemical energy turns into electric energy when there is a complete path or wire from the positive end of the battery to the negative end. The motor turns the electric energy into motion energy.


Battery
Stored chemical
Closed wire path
Motor
Turns electric energy into motion energy
Propeller
Moves air

2. Does anyone have to do any work in order to store the energy in the battery? ____________________________________

3. How do you know that? ____________________________________
____

LESSON 3: ELECTRIC CIRCUITS, POLARITY, ENERGY TRANSFER

OVERVIEW

The students will use more of the Capsela components to explore simple electric circuits, battery polarity, and direction of current. They will find that electric effects occur only if the circuit is complete, or closed. The lighting of a lamp does not depend on the current direction, but the motor reverses direction when the current is reversed.

PERFORMANCE OBJECTIVE

Your students will be able to follow a circuit diagram to connect a battery to a lamp or a motor, keeping track of the polarity of the connections so that they can reverse current flow. They should observe the effect of reversing current in a lamp and in the motor. They should be able to expand the simple circuit, and to wire in a switch.

PERFORMANCE STANDARD

Each student should be able to connect the simple battery to a lamp and to the motor. Each should be able to reverse the connections in order to reverse the direction of current and to connect and use the switch. Each should be able to report results by drawing circuit diagrams and describing the results orally or in writing.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
10	Oct. Conn.	1	23	Wire Leads	2
14	Coupler	1	24	Lamp*	1
15	Coupler Cap	1	33	Propeller	1
21	Sm. Bat. Case	1	Battery		1

Student Hand-Out Sheet

*Red lamp cover snaps off to tighten the bulb.

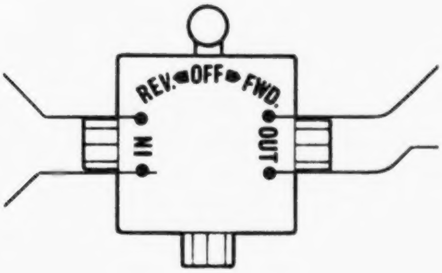
#3 TEACHERS' NOTES: ELECTRIC CIRCUITS, POLARITY, ENERGY TRANSFER

Technically, electric current in ordinary wires is produced by the movement of negatively charged electrons. The assignment of the names "positive" and "negative" was made by Benjamin Franklin before anyone knew about electrons or atomic structure. Consequently, negative electrons leave the negative (-) end of a battery, move through the circuit, and enter the positive (+) end of the battery. Nevertheless, modern engineering practice and advanced school texts refer to the direction of current as the direction of positive charge movement. (Negative electrons moving to the left produce the same effect as positive electric charge carriers moving to the right.) There are good historical and technical reasons for this practice. You can avoid confusion simply by referring to "electricity." What it is that moves need not be discussed at the elementary school level.

Notice, also, that there is no need to go into the details of how the electricity produces light in the lamp or motion in the motor. For your own background information, the light is produced by the heating of the tungsten filament in the lamp to white hot temperatures (several thousand degrees). The heating is produced by the jostling of the electrons as they pass through the high resistance tungsten wire. The heat produced doesn't depend on the direction of the electrons. Much less heat is produced in the copper wire leads, which present very little resistance to the electron flow.

The electric current in the motor produces an electromagnet. That electromagnet spins in the magnetic field of a built-in permanent magnet (in this type of motor). Because the direction (north-south) of an electromagnet depends on the direction of the current, the direction of the motor spin reverses if the current is reversed.

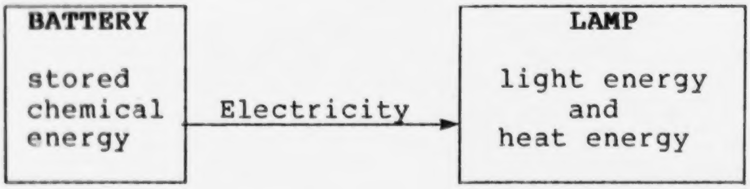
You might want to challenge a precocious student to figure out the circuit inside the switch box (without taking it apart!). It is called a "double-pole, double throw" switch box.



Switch is shown open (off position). If the switch is swung down toward forward (FWD) upper input contact is connected to upper output contact.

If the switch is swung down toward reverse (REV) upper input contact is connected to lower output contact.

Emphasize the energy transformation into light by having the students answer the last question in the work sheet in terms of input boxes:


BATTERY
stored chemical energy
Electricity
LAMP
light energy and heat energy

With the single battery, the increased temperature of the little light is just barely noticeable. Most children know a 60 watt bulb in a home lamp is very hot. The electrical energy goes mostly into heat. With an ordinary incandescent bulb, only a few percent of the energy goes into light.

STUDENT HAND-OUT SHEET #3
ELECTRIC CIRCUITS, POLARITY, ENERGY TRANSFER

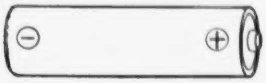
MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
10	Oct. Conn.	1	23	Wire Leads	2
14	Coupler	1	24	Lamp	1
15	Coupler Cap	1	33	Propeller	1
21	Sm. Bat. Case	1		Battery	1

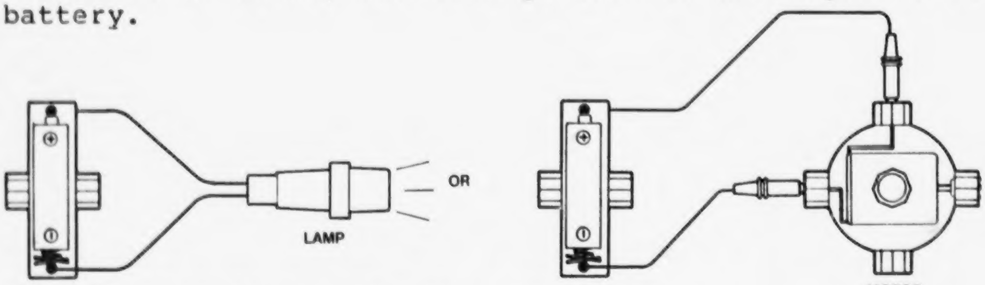
Electricity comes out of a battery, but only if it can get back in again!

There has to be a complete, closed path, or else there won't be any electric current.

Look at the battery. The two ends are different. One is marked + (positive). The other is called - (negative).



The path for the current is called a circuit. It is usually made of a wire lead or metal in some other shape. The wire lead must start at the positive end of the battery, go through the electric lamp or motor or stove, and then go back to the negative side of the battery.



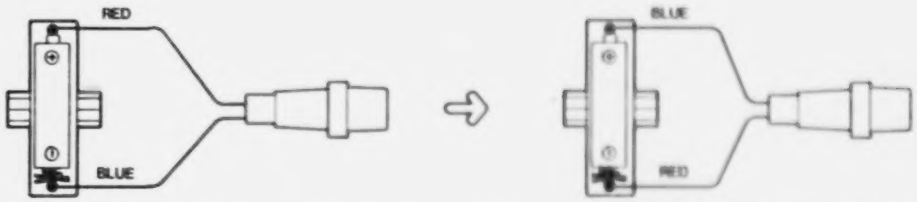
Connect the circuit to make the lamp light.

1. What happens when you disconnect the wire from the + side of the battery? ______________________________
   ____

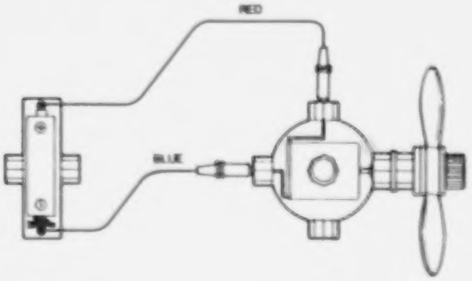
2. What happens when you disconnect the wire from only the - side of the battery? ______________________________
   ____

3. What happens if you connect the wires so that the current in the bulb is in the opposite direction? ____________________

STUDENT HAND-OUT SHEET #3
ELECTRIC CIRCUITS, POLARITY,
ENERGY TRANSFER (Continued)



Now connect the battery to the motor. Put on the propeller so that you can see which way the motor turns.

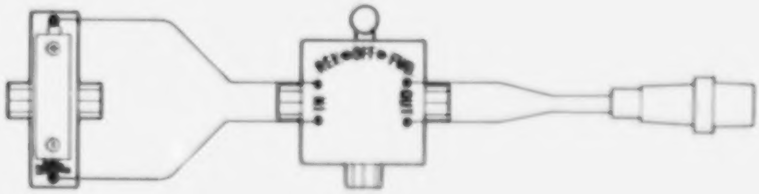


*Don't allow the propeller to hit anyone as it turns.

4. What happens if you connect the wires so that the current in the motor is in the opposite direction? ______________________
____

Instead of connecting and disconnecting the wire leads by hand, you can use the switch box. In one position the switch stops the electricity by opening the circuit.

Connect the switch box and then send electricity into the lamp.



5. Feel the lamp when it is lighted. Is it warm? ________________

6. Are the light bulbs in your lamps at home hot? ________________
(Caution: Do Not Touch The Light Bulbs!)

7. Where does the energy go when electricity goes through the lamp? ____
____

LESSON 4: SPEED REDUCTION, GEAR TRANSFORMATION OF SPEED AND TORQUE

OVERVIEW

The students continue their exploration of the Capsela components by studying the speed reduction gears. Students will measure the reduction ratios and observe the qualitative effects on both speed and torque.

The formal connections between speed, torque, and power will be made in later lessons.

PERFORMANCE OBJECTIVE

Your students will observe, and learn the names of several types of gears. They will measure and characterize each of these in terms of the speed reduction ratios: input turns to output turns. They will observe the qualitative effect that these reduction gears have on torque output. Part of the purpose of this lesson is to lay the groundwork for the efficient building of more complex machines and more sophisticated experiments.

PERFORMANCE STANDARD

Each student will be able to measure the approximate input-output ratio of the reduction gears. Each will be able to characterize these units in terms of their effects (high speed in - low speed out) and also specify the effect on the direction of turning (in-line, opposite, perpendicular).

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor Caps	1	15	Coupler Cap	2
2	Speed Red. Cap.	1	21	Sm. Bat. Case	1
3	Worm Gear Cap.	1	22	Switch Box	1
4	Crown Whl. Cap.	1	23	Wire Leads	4
5	Int. Gear Cap.	1	33	Propeller	1
10	Oct. Conn.	2	34	Impeller	2
14	Coupler	2	Battery		1

Student Hand-Out Sheet

#4 TEACHERS' NOTES: SPEED REDUCTION, GEAR TRANSFORMATION OF SPEED AND TORQUE

The effects of the worm gear and the speed reduction gear are dramatic, both in terms of their speed reduction and their torque (or turning power) increase. The speed reduction effects of the crown gear (2 to 1) and internal gear (3 to 1) are not so obvious. However, the students should note the direction of the outputs, which will be very important in building some of the machines.

Friction prevents the reduction gears from being driven backwards, and will also prevent quantitative comparisons of work-in to work-out. For instance, it is hard to see the expected speed-up of the propeller when driven by the crown gear in the backward direction, because the extra friction load reduces the motor speed.

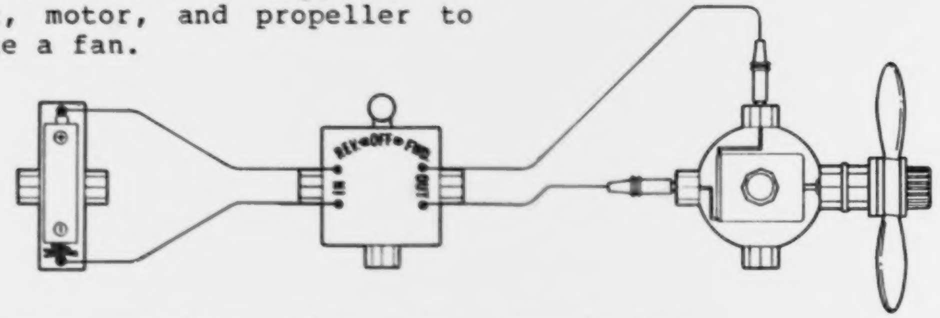
In subsequent lessons, the students will learn how to design machines by logical choice of gears to speed up, slow down, exert more or less torque, and to change direction of drive. This lesson is just the first stage in that learning process.

STUDENT HAND-OUT SHEET #4: SPEED REDUCTION, GEAR TRANSFORMATION OF SPEED AND TORQUE - "SLOWING THE ACTION"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor Caps	1	15	Coupler Cap	2
2	Speed Red. Cap.	1	21	Sm. Bat. Case	1
3	Worm Gear Cap.	1	22	Switch Box	1
4	Crown Whl. Cap.	1	23	Wire Leads	4
5	Int. Gear Cap.	1	33	Propeller	1
10	Oct. Conn.	2	34	Impeller	2
14	Coupler	2		Battery	1

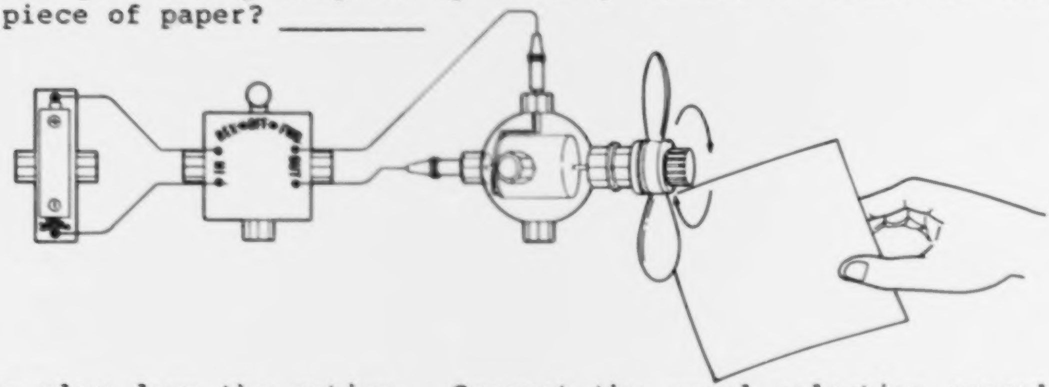
Connect the battery, switch box, motor, and propeller to make a fan.



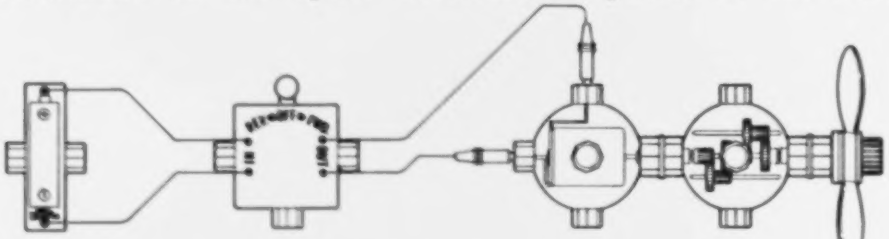
1. The propeller spins fast, doesn't it? __________ Aim it at your hand like a fan, but don't let it hit your hand! See what happens when you reverse the fan direction by reversing the switch.

2. Can you easily stop the propeller with your finger? ________

3. Can you easily stop it by letting it hit a corner of this piece of paper? _________



Let's slow down the action. Connect the speed reduction capsule between the motor and the propeller. (Note to connect the grey gear connector on the speed reduction capsule to the motor.)



4. What happened to the propeller speed? __________________________

5. Is it easier or harder to stop the spinning propeller with your finger? ________

STUDENT HAND-OUT SHEET #4
SPEED REDUCTION, GEAR TRANSFORMATION OF SPEED AND TORQUE (Continued)

6. Can you stop the propeller by letting it hit a corner of this piece of paper while you hold the other end? ____________________

7. Now connect the gear capsule backward, so that the grey connector is fastened to the propeller. What happens?

____

Do the same experiment with the crown gear capsule.

8. Why is it called a crown gear? ____________________________________

Attach the small gear to the motor and attach the propeller to the top of the crown gear.

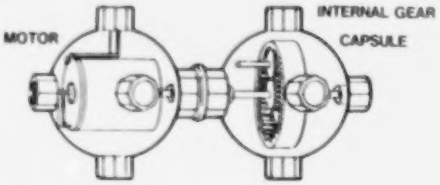
9. Does the propeller spin faster or slower than with just the motor? ____

Try the same experiments with the worm gear capsule and the internal gear capsule.

10. Worm gear capsule: Faster or slower than with just the motor? ____

11. Does the edge of this paper stop it? ______________________________

Internal gear capsule: (The little gears should face the motor)

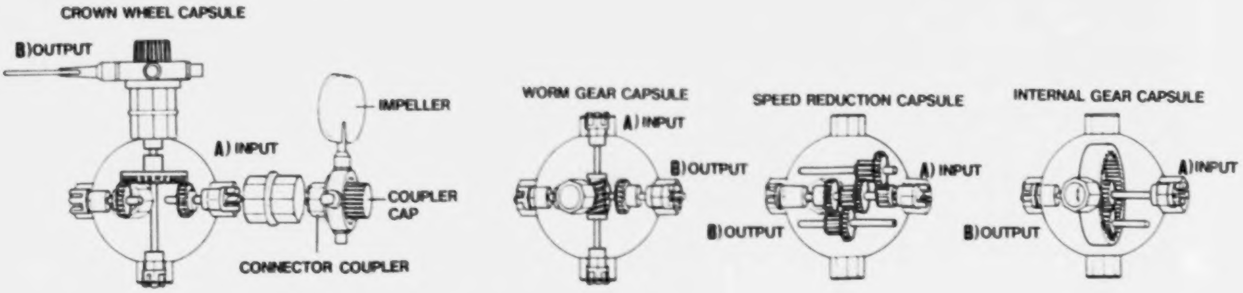


12. Does the propeller spin faster or slower than with only the motor? ____

13. Can the edge of this paper stop the propeller? __________________

Now, disconnect the gear capsules from the motor. Take each capsule, one at a time, and connect an impeller blade at input and output. (The small gear is input)

STUDENT HAND-OUT SHEET #4
SPEED REDUCTION, GEAR TRANSFORMATION OF SPEED AND TORQUE (Continued)


CROWN WHEEL CAPSULE
B)OUTPUT
A) INPUT
IMPELLER
COUPLER CAP
CONNECTOR COUPLER
WORM GEAR CAPSULE
A) INPUT
B)OUTPUT
SPEED REDUCTION CAPSULE
A) INPUT
B)OUTPUT
INTERNAL GEAR CAPSULE
A)INPUT
B)OUTPUT

14. Turn the input side around and around until the output blade goes around one full circle.

A. Crown Wheel Capsule: Number of input turns ________

B. Worm Gear Capsule: Number of input turns ________

C. Speed Reduction Capsule: Number of input turns ________

D. Internal Gear Capsule: Number of input turns ________

15. Which gear capsule should you use if you want the propeller to turn as slowly as possible? ____________________

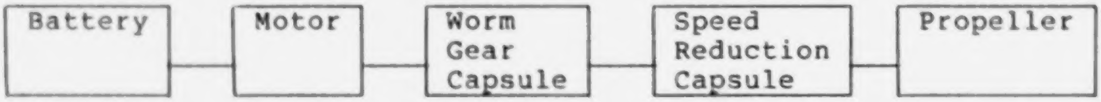
16. A. Which gear capsule reduces the speed only a small amount?

____

B. By how much is the speed reduced? ____________________

17. Which gear capsule should you use if you want the propeller to shove very hard against something? ____________________

18. What happens if you connect the:


Battery
Motor
Worm Gear Capsule
Speed Reduction Capsule
Propeller

(Try it and find out) ____

____

LESSON 5: ENERGY AND SPEED TRANSFORMATION: THE RACING CAR

OVERVIEW

The students will tie together the concepts and techniques from the previous lessons and build a complex toy machine. They will learn to follow the building directions which emphasize how to follow a logical design system based on the observed characteristics of the capsules.

PERFORMANCE OBJECTIVE

Your students will be able to connect a complex toy machine following written instructions and diagrams. They will be able to follow the design requirements to choose among components.

PERFORMANCE STANDARD

Each student should be able to indicate (orally or in writing) the proper choice of components in order to make the high speed motor drive a low speed toy car. The car will work in both forward and reverse directions.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	22	Switch Box	1
8	Trans. Cap.	1	23	Wire Leads	4
10	Oct. Conn.	8	25	Lg. Wheel	4
14	Coupler	4	28	Lg. Tire	4
			Battery		1

Student Hand-Out Sheet

#5 TEACHERS' NOTES: ENERGY AND SPEED TRANSFORMATION: THE RACING CAR

This lesson contains two new technical words: perpendicular and torque. "Perpendicular" is such a big word that once seen it is easily remembered. You can illustrate the word by pointing out things in the room that are perpendicular to each other. A wall is perpendicular (or at right angles) to the one next to it, and each is perdendicular to the floor and ceiling.

"Torque" is easy to remember because of its sound and the presence of the letter "q." Technically, torque is the "turning force." You can exert a large torque to make something turn by exerting a large force on a large lever arm. In opening a heavy door, for instance, you intuitively seek to increase your torque by pushing against the outside edge of the door, as far away as possible from the hinges. Your students don't have to learn any formal definition of torque at this point.

When the car is first built, using the straight-through transmission capsule, it may be able to move if the battery is fresh. However, friction is so great in the system that the car will not be able to move fast or to climb a slight grade.

In talking with your students about the car, emphasize the reason for using each component. Why was the crown gear used? Why was it oriented so that the small gears were driven, instead of the crown itself? What would happen if the crown was driven? (Some students may want to find out.) What happens if the internal gear capsule is used instead of the reduction gear?

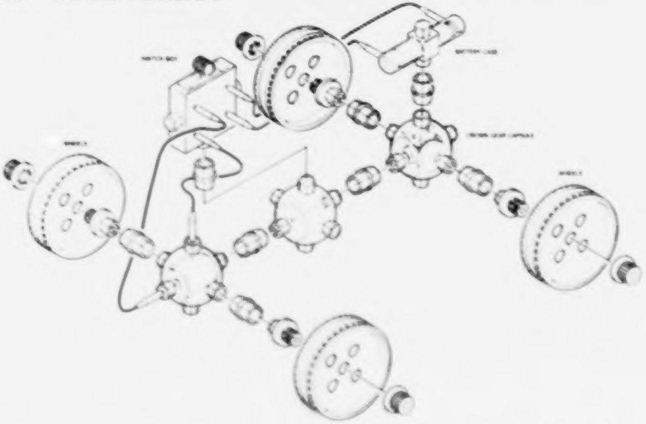
STUDENT HAND-OUT SHEET #5
ENERGY AND SPEED TRANSFORMATION: THE RACING CAR
"PUTTING IT ALL TOGETHER"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	22	Switch Box	1
8	Trans. Cap.	1	23	Wire Leads	4
10	Oct. Conn.	8	25	Lg. Wheel	4
14	Coupler	4	28	Lg. Tire	4
				Battery	1

It's time to put it all together. Now that you know how the motor and gears work, let's make a car. The motor spins very fast. Maybe you can make the car's wheels go that fast.

Here is one design. The motor is in-line. It spins perpendicular to the wheels. To make the wheels turn in the right direction you must use a gear that turns in a perpendicular direction. The crown gear does that.



1A. Does the motor make the wheels spin fast when the wheels are not touching the floor? ____________________

B. Now -- how fast does the car move when the wheels are on a smooth floor? ____________________

What's wrong? You have a high speed motor, but it has low turning force. It produces low torque (tork). You'll have to use some gears between the motor and the wheels. Instead of the transmission capsule (which has no gears), use a capsule that slows down the speed (and increases the torque).

2. Which capsule will you try? ____________________

3. Does it make the car go? ____________________

4. Can the car climb a small hill? ____________________

5. Did the extra gear increase the torque? ____________________

LESSON 6: COMPLEX MACHINE: THE REVOLVING TOWER

OVERVIEW

The students get more experience with the same components used in making the car, but construct a machine that behaves very differently. After following specific directions on how to build the first version, they are then challenged to change the design to produce a different effect. In order to do so, they must analyze the nature and behavior of the crown gear capsule.

PERFORMANCE OBJECTIVE

Your students will gain more experience in following written instructions and diagrams in order to build a complex machine. They will also learn how to solve a design problem by analyzing the properties of one of the components.

PERFORMANCE STANDARD

Each student should be able to construct the rotating tower, and then be able to transform it by changing the orientation of the crown gear. The student should be able to explain orally or in writing why this change produces the desired effect.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	8	25	Lg. Wheel	4
14	Coupler	4	28	Lg. Tire	1
15	Coupler Cap	4	Battery		1

Student Hand-Out Sheet

#6 TEACHERS' NOTES: COMPLEX MACHINES: THE REVOLVING TOWER

Although your students have explored the properties of the crown gear before, this challenge exercise requires them to take another look at it.

Lesson 9 is explicitly concerned with friction. At the end of this exercise there is a question about using tires on all four wheels. As the students will observe, the tires on the two idler wheels will drag on the floor, preventing the device from moving. The drive wheels cannot produce enough force to overcome this friction. The students are asked to describe their observation in their own words, but need not be taught much more about friction at this point.

Some of the words used in the student directions may be new to some students. Perhaps these words should be written on the board, and students should be asked to define them by giving examples or illustrating them. These words are: revolve (and revolving), transform, challenge.

STUDENT HAND-OUT SHEET #6
COMPLEX MACHINE: THE REVOLVING TOWER

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	8	25	Lg. Wheel	4
14	Coupler	4	28	Lg. Tire	1
15	Coupler Cap	4		Battery	1

Now you can make Capsela go in circles.

Use the same parts you used for the racing car, except remove three of the large tires.

You need: A battery to deliver energy

A switch box to turn the electric current on or off, or to change its direction

A motor to transform electrical energy into motion energy

A speed reduction gear between the high speed motor and the low speed wheels (and this gear will also produce high torque at the wheels from the low torque at the motor)

A crown gear to change the drive in a perpendicular direction

4 wheels for the tower to travel on

Follow the diagram and build the revolving tower.

Be sure you get the crown gear in the right position. The crown should be on top.

Now -- after you make the tower, and make it revolve, here's a challenge!

1. Can you use the same parts (no more, no less) and make the tower move in a straight line instead of revolving? __________

(Here's a hint. Look at the way the crown gear works.)

2. How can you drive it so that two oppposite sides turn in the same direction? ______________________________

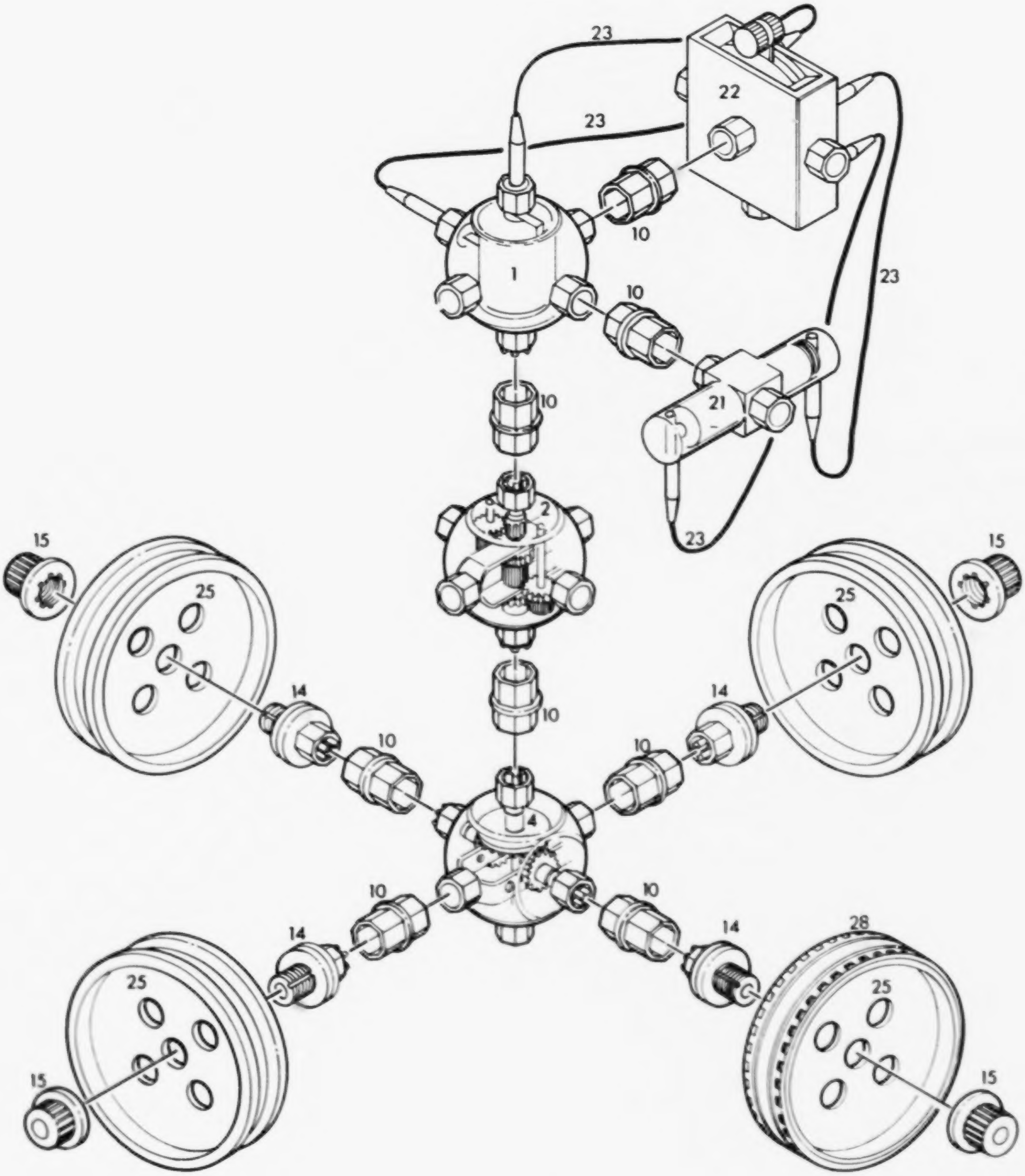
Can the tower move forward or backward if all four wheels have tires? Try it and see.

3. What happens, and why? ______________________________

LESSON 6: REVOLVING TOWER

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	8	25	Lg. Wheel	4
14	Coupler	4	28	Lg. Tire	1
15	Coupler Cap	4	Battery		1


23
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LESSON 7: FORCE: DEMONSTRATED WITH A CAPSELA VEHICLE

OVERVIEW
The students face another design challenge in this lesson. They must organize the listed components to create a vehicle that can exert as large a force as possible. They should use judgment and prior experience in choosing the gears. In the process, the concept of force is introduced, and operationally defined in terms of a measurement with a spring scale.

PERFORMANCE OBJECTIVE

Your students will be able to design and build Capsela vehicles to exert as large a force as possible. The students should learn how to measure this force with a spring scale.

PERFORMANCE STANDARD

Each student should be able to build a Capsela car, truck or vehicle of his or her choice and explain orally or in writing why the particular gears were chosen. Each student should be able to measure the force exerted by the vehicle.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	22	Switch Box	1
5	Int. Gear Cap.	1	23	Leads	4
9	Clear Capsule	3	25	Lg. Wheel	4
10	Oct. Conn.	12	28	Lg. Tire	4
14	Coupler	4	Battery		1
			Force Spring Scale		

Student Hand-Out Sheet

#7 TEACHERS' NOTES: FORCE: DEMONSTRATED WITH A CAPSELA VEHICLE

At the very least, a student can assemble the components to make a car again. However, challenge your students to try other possibilities. Maybe direct drive of the wheels by the motor without reduction gears will produce large pulling force; maybe two of the reduction gears should be mounted in series.

The pulling force will depend on the battery quality. If you organize a contest to see who can design a vehicle with the greatest force, the student with the freshest battery will probably win.

Force is defined here as simply a push or a pull. The spring scale is calibrated in Newtons or grams. In the English (now American only) system of units, force is measured in pounds. In the metric system, the unit is the newton. 1 newton = 0.22 pound (about 1/5 pound) 1 pound = 4.4 newtons. There is no need for students to memorize these units at this stage. It is sufficient if they begin to feel various measured forces with their muscles.

STUDENT HAND-OUT SHEET #7
FORCE: DEMONSTATED WITH A CAPSELA VEHICLE "TUG OF WAR"

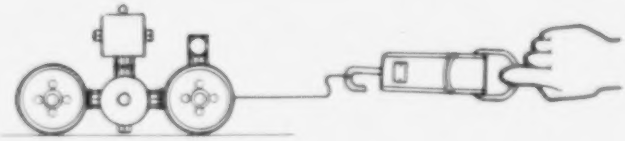
MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	22	Switch Box	1
5	Int. Gear Cap.	1	23	Leads	4
9	Clear Capsule	3	25	Lg. Wheel	4
10	Oct. Conn.	12	28	Lg. Tire	4
14	Coupler	4		Battery	1
				Force Spring Scale	

Can you build a Capsela vehicle with lots of pull?

Use the battery and motor and any gears you want.

Hook your vehicle to the force spring scale.

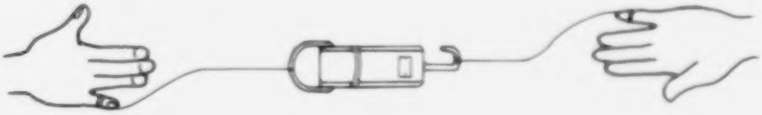


Draw a diagram of your vehicle and label the parts.

1. Which gear capsules did you use? ______________________________
____

2. How much force does it pull? ______________________________

3. How much force can you produce with your little finger? (without moving your hand!) ______________________________



4. In order to produce a large force, what happened to the speed of your vehicles? ______________________________

5. If you make a vehicle that goes very fast, will it also pull with a large force? ______________________________

LESSON 8: LEVERAGE: THE LEVER WITH A CAPSELA VEHICLE

OVERVIEW

The students will explore the properties of the lever -- the simplest machine. As in Lesson 7, they will be challenged to exert as large a force as possible with a Capsela vehicle. However, this time the vehicle can push or pull on a horizontal level. By varying the input-arm to output-arm length ratio, the students can increase the final force exerted, as measured with the spring scale.

PERFORMANCE OBJECTIVE

Your students will be able to use a lever to increase the force exerted by the Capsela vehicle. They will observe the effects produced by having long input-arm and short output-arm, or vice versa. The general rule for levers will be presented and illustrated by diagrams and use of other common levers.

PERFORMANCE STANDARD

Each student will be able to use the lever with several combinations of input-output ratios. Each student will be able to describe orally or with diagrams how to choose the lever arm length in order to increase the force output.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Leads	4
5	Int. Gear Cap.	1	25	Lg. Wheel	4
9	Clear Capsule	3	28	Lg. Tire	4
10	Oct. Conn.	12	41	Arm Bar	1
12	Sm. Bar Conn.	1	42	Hook & String	2
14	Coupler	4	Battery		1
15	Coupler Cap	4	Force Spring Scale		

Student Hand-Out Sheet

#8 TEACHERS' NOTES: LEVERAGE: THE LEVER WITH A CAPSELA VEHICLE

The simple machines are the lever, inclined plane, wheel and axle, and pulley. Screws are circular inclined planes. Wheels are essentially circular levers. Gears are variations of the wheel and axle.

In this lesson we use the Capsela vehicle from the previous lesson as a device to exert a known force. This force can be multiplied by the use of a horizontal lever. Students should observe this effect both with the vehicle and force meter, and in their muscles by using the lever to push against a book (or other weight).

The lever rules are given in the student handout sheet. It should be a matter of your judgment whether students should memorize the formulas and use them quantitatively. Most sixth graders can handle the arithmetic.

It would be instructive to have other common levers availabe for use and exploration. In each case, ask the students to point out the input lever-arm, the output lever-arm, and to feel the resulting input and output forces. All common lever devices increase output force at the cost of requiring larger input distances The "mechanical advantage" (output force/ input force) is greater than 1. However, our arm and leg muscle-levers are just the opposite. When you raise your hand a large distance (the output), your biceps pull with a large force for only a short distance (the input). (The mechanical advantage is about 1/7.) The advantage of this arrangement is that the hand can move a large distance quickly, and thus at high speed. Humans are good at throwing things.

In using the lever formula quantitatively, any units can be used for force and for distance as long as they are the same units for input and output. For example:

(pounds in) x (feet, input distance) = (pounds out) x (feet, output distance)
(newtons in) x (centimeters, input distance) = (newtons out) x (cm, output)

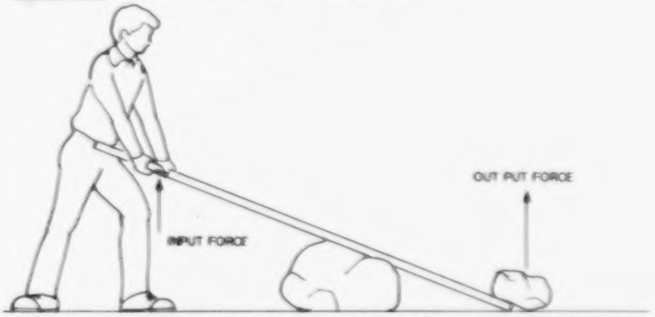
STUDENT HAND-OUT SHEET #8
LEVERAGE: THE LEVER WITH A CAPSELA VEHICLE

MATERIALS: CAPSELA SCIENTIFIC

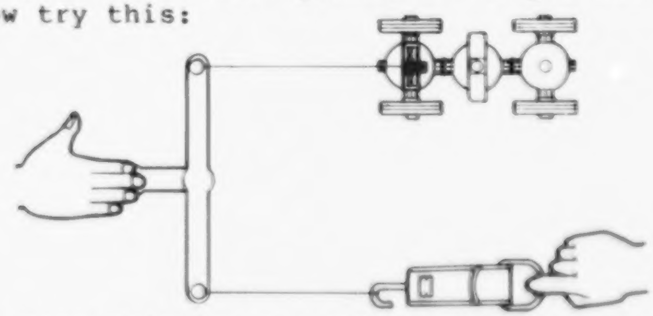
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Leads	4
5	Int. Gear Cap.	1	25	Lg. Wheel	4
9	Clear Capsule	3	28	Lg. Tire	4
10	Oct. Conn.	12	41	Arm Bar	1
12	Sm. Bar Conn.	1	42	Hook & String	2
14	Coupler	4		Battery	1
15	Coupler Cap	4		Force Spring Scale	

1. How much force did your vehicle produce? ________
(See Lesson 7)

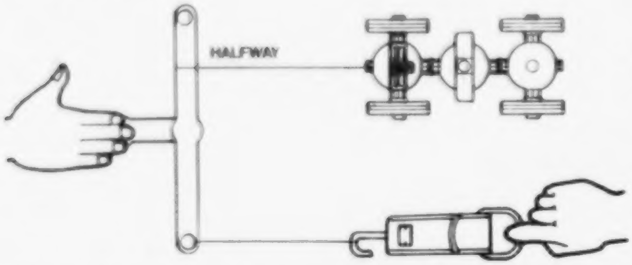
You can do better than that! Use your leverage. Here's how to make a lever for your vehicle.

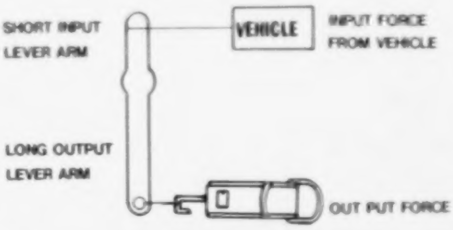

OUT PUT FORCE
INPUT FORCE

2. Does this lever produce a larger force from your vehicle? ____
Now try this:

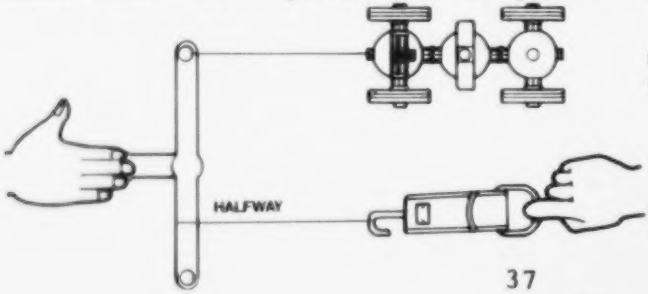


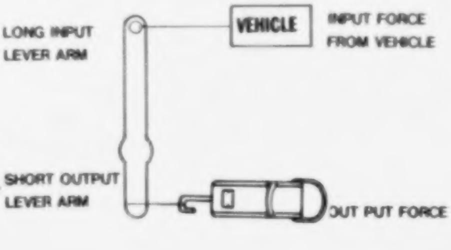
3. Does this lever produce a larger force? ________________________
Then try this:




SHORT INPUT
LEVER ARM
VEHICLE
INPUT FORCE
FROM VEHICLE
LONG OUTPUT
LEVER ARM
OUT PUT FORCE

4. Does this lever produce a larger force? ________________________



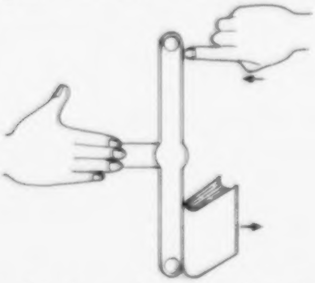

LONG INPUT
LEVER ARM
VEHICLE
INPUT FORCE
FROM VEHICLE
SHORT OUTPUT
LEVER ARM
OUT PUT FORCE

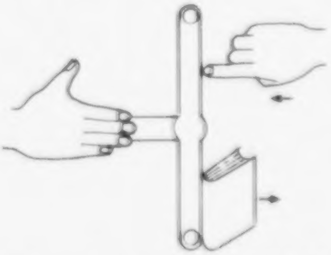
STUDENT HAND-OUT SHEET #8
LEVERAGE: THE LEVER WITH A CAPSELA VEHICLE (Continued)

5. To get the most leverage, should you use a long input arm or a short input arm?

____

Use the lever arm to produce forces with your fingers. Have the output lever arm shove on a heavy book.

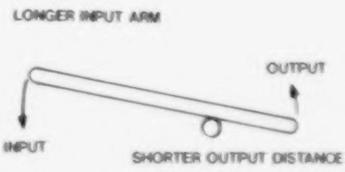




The lever is a simple machine. It turns small force into large force -- or large force into small force.

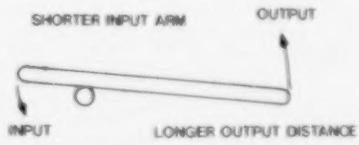
But -- you can't get something for nothing! Look closely at the lever. If the input-arm is longer than the output-arm you can produce a larger force at the output. But you have to shove for a longer distance at the input.

Input	Output
long lever arm	small lever arm
small force in	large force out
large distance moved	small distance moved


LONGER INPUT ARM
OUTPUT
INPUT
SHORTER OUTPUT DISTANCE

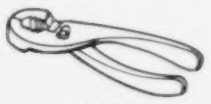
or

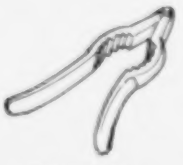
Input	Output
small lever arm	long lever arm
large force in	small force out
large distance moved	small distance move

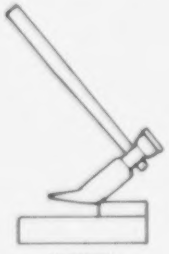

SHORTER INPUT ARM
OUTPUT
INPUT
LONGER OUTPUT DISTANCE

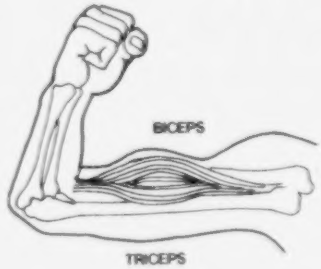
(input force) x (input distance) = (output force) x (output distance)

You use lots of levers:




NUTCRACKER




BICEPS
TRICEPS

Draw pictures of others levers that you use:

LESSON 9: INCLINED PLANE, AND MEASUREMENT: TRACTOR

OVERVIEW

Your students will use another simple machine -- the inclined plane. They will be challenged to find a way for the Capsela tractor to climb as high as possible. If a gentle slope is provided, the tractor can exert enough force to keep going, but will have to travel a long distance to rise a small amount. With a steeper grade, more force will be required but it will take a shorter distance to rise the same amount. This activity will be used to give a definition of work.

PERFORMANCE OBJECTIVE

Your students will experiment with the inclined plane. They will find that a small slope allows a small force to be exerted in order to raise an object, but a large distance must be traveled. A steep slope requires a large force but only for a short distance.

PERFORMANCE STANDARD

Each student will be able to report orally or in writing on the advantages and disadvantages of using an inclined plane to lift something.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Leads	4
2	Spd. Red. Cap.	1	25	Lg. Wheel	2
4	Cr. Wheel Cap.	1	27	Sm. Wheel	2
10	Oct. Conn.	7	28	Lg. Tire	2
14	Coupler	2	30	Sm. Tire	2
15	Coupler Cap	2	42	Hook & String	1
17	Axle Support	1	Flat Board or Shelf		
18	Long Axle	1	Books for Spacers		
21	Sm. Bat. Case	1	Force Spring Scale		
22	Switch Box	1	Battery		1

Student Hand-Out Sheet

#9 TEACHERS' NOTES: INCLINED PLANE, AND MEASUREMENT: TRACTOR

Like all machines, the inclined plane does not save any work. Instead, it allows a choice between force-exerted and distance-moved-because-of-the-force. Inclined planes are used when heavy objects must be lifted, not to save work, but because it takes less force. However, you have to exert the smaller force through a larger distance. For instance, you might not be able to lift a 200 pound refrigerator two feet up onto a truck. But if you have a 10 foot board you can prop it between floor and truck. Then you can roll the refrigerator on caster wheels along the 10 feet, which also yields a rise of 2 feet. You might expect that the required force would be 2/10 of the 200 pounds, or 40 pounds. Because of friction you would have to exert a force greater than 40 pounds, but it is usually still worthwhile. Work-in is equal to or greater (because of friction) than work-out.

(greater than 40 lbs) x (10 ft) = (200 lbs) x (2 ft)

The extra work required by friction turns into heat. (The students will explore friction in the next lesson.)

A bookcase is a good source for a flat, rigid inclined plane. Use one of the shelves. You can also use the books for spacers at the end to change the grade.

Here is an extra activity that you might suggest to some of your students. Loosen the gear connection in the Capsela tractor so that the wheels turn freely. Then use the spring scale to measure the force needed to pull the car up various grades at constant speed. The steeper the grade, the greater the force needed. (If the grade is 100% -- straight up -- the force needed is equal to the weight of the tractor. If the grade is 0 -- horizontal -- the force needed is just equal to the friction of the wheels.)

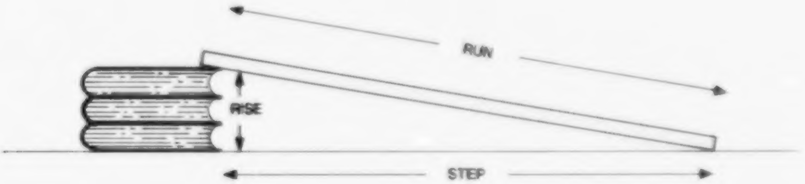
Note that we define "work" in the student handout sheet but do not make a big point of it yet. You may wish to emphasize the definition now, and draw attention to the rule for simple machines: work in ≥ work out.

(input force) x (input distance) ≥ (output force) x (output distance)

You may want to show your students a large screw or threaded bolt, the bigger the better. Describe it as a circular inclined plane -- that's all it is!

Note that three new words are used: inclined plane, gravitational, and grade. The first two are defined in context, but probably you should draw special attention to them. (In answer to a student question, if the tractor drops, its gravitational energy turns into motion energy, until it hits the floor. Then, it turns into heat and sound.) The word "grade" is one way of defining the slope or pitch of a road. It is the word usually used by road engineers. Note that it is the ratio of "rise" to "run." The "slope," which is more used in mathematics, is the ratio of "rise" to "step." For a small grade or slope, there is little difference. However, the grade of a vertical wall is 1 (or 100%); its slope is infinite. When a road engineer says that a mountain road has a grade of 10%, she means that it rises 0.1 mile for every mile you drive along it.

Instead of measuring the grade of the student's inclined planes, always use 100 cm for the "run." Then the calculations and arithmetic are simple. For the "rise," always measure the height from the horizontal surface to the end of the 100 cm mark.



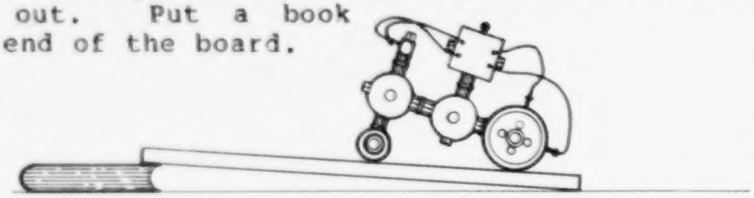
$$\text{SLOPE} = \frac{\text{RISE}}{\text{STEP}} \qquad \text{GRADE} = \frac{\text{RISE}}{\text{RUN}}$$

STUDENT HAND-OUT SHEET #9 INCLINED PLANE, AND MEASUREMENT: TRACTOR "CLIMBING HILLS"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Leads	4
2	Spd. Red. Cap.	1	25	Lg. Wheel	2
4	Cr. Wheel Cap.	1	27	Sm. Wheel	2
10	Oct. Conn.	7	28	Lg. Tire	2
14	Coupler	2	30	Sm. Tire	2
15	Coupler Cap	2	42	Hook & String	1
17	Axle Support	1		Flat Board or Shelf	
18	Long Axle	1		Books for Spacers	
21	Sm. Bat. Case	1		Force Spring Scale	
22	Switch Box	1		Battery	1

Your Capsela tractor can travel pretty fast on a flat surface. Can it climb a hill? Get a long flat board and find out. Put a book under one end of the board.



Measure the length of the board and the thickness of the book. If the board is 100 centimeters long and the book is 4 centimeters thick, then the grade is 4/100 or 1/25. For every 25 cm of travel, the board rises 1 cm.

Make the slope steeper and steeper by adding more books, one at a time.

1. What is the steepest grade that your tractor can go up?
   __________/100

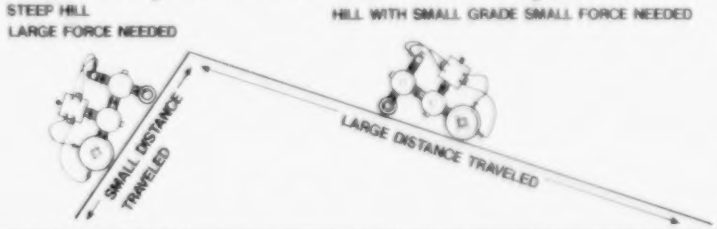
When your tractor climbs up high, it has gravitational energy. It takes chemical energy from the battery to turn into motion energy, which turns into gravitational energy.

2. If the car then dropped to the floor, what kind of energy would the gravitational energy turn into? ____________________

Maybe with the inclined plane (the hill), we can get something for nothing! Here's how. Use a long hill with a small grade. Your tractor can climb very high by using only a small force. When it gets very high it will have a lot of gravitational energy, but only a small force was used. (Use a force spring scale to measure force.)

3A. Did you really get something for nothing? ____________________

3B. Look at the diagram below and then explain.



____

____

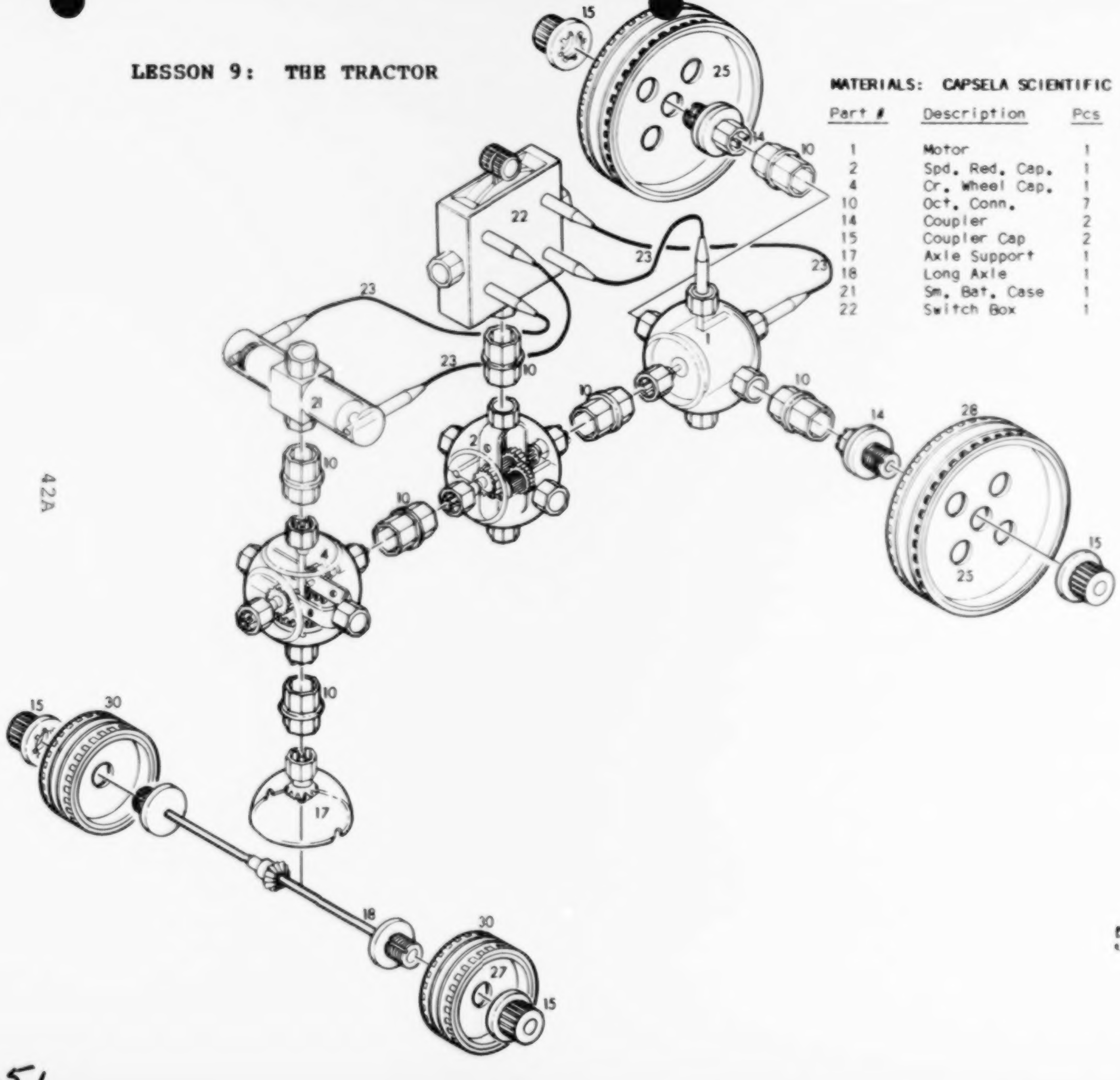
____

To do work you have to push or pull something that moves. The work you do is equal to the force times the distance moved in the direction of the force.

LESSON 9: THE TRACTOR

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Leads	4
2	Spd. Red. Cap.	1	25	Lg. Wheel	2
4	Cr. Wheel Cap.	1	27	Sm. Wheel	2
10	Oct. Conn.	7	28	Lg. Tire	2
14	Coupler	2	30	Sm. Tire	2
15	Coupler Cap	2	42	Hook & String	1
17	Axle Support	1		Flat Board or Shelf	
18	Long Axle	1		Books for Spacers	
21	Sm. Bat. Case	1		Force Spring Scale	
22	Switch Box	1		Battery	1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42A

LESSON 10: FINDING THE LOST ENERGY, FRICTION AND HEAT ENERGY

OVERVIEW

The students will review various situations in the previous lessons where stored energy turned into motion energy and then apparently disappeared. They will observe several examples of friction, including traction, and will experience the increase of temperature when motion energy turns into heat energy.

PERFORMANCE OBJECTIVE

Your students will be able to connect several combinations of Capsela components and link the observed results with the effects of friction. They will be able to explain the role of friction in simple cases, including the dissipation of energy and the traction of tires.

PERFORMANCE STANDARD

Each student will be able to assemble devices that illustrate traction and slipping friction. Each student should be able to explain orally and with diagrams how energy is transformed from stored to motion to heat. Each student should be able to demonstrate how the temperature rises when motion energy is lost.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Leads	4
9	Clear Capsule	1	25	Lg. Wheel	4
10	Oct. Con.	10	28	Lg. Tire	4
12	Sm. Bar Conn.	1	41	Arm Bar	1
14	Coupler	4	Force Spring Scale		
15	Coupler Cap	4	Battery		1

Student Hand-Out Sheet

#10 TEACHERS' NOTES: FINDING THE LOST ENERGY, FRICTION AND HEAT ENERGY

Most materials stick together, more or less. This is true of solids, liquids, and gases. Because of the sticking, it takes a force to move things past each other if they are touching. Because the force has to be continually exerted in the direction of motion, work is done. All the work used to overcome friction goes into heat energy. If an object already has motion energy, it will continually lose it to friction. The object slows down and the system gets hotter.

The Capsela machines slow down and stop when the energy source is turned off, but it is not possible to detect the increase in temperature with your hands. Therefore, we propose the hand rubbing exercise. The increase of temperature in your hands or on the table top, is quite noticeable.

There is a rather complicated reason why it is hard to drive the speed-reduction capsule gear backwards. Of course there is friction in the gears, about the same amount between any two in a pair. For one gear to turn another, the drive wheel must provide at least as much torque as the friction torque. At the high speed end, the driven gear can provide high torque, sufficient to overcome the friction at that wheel and drive the next gear, which in turn increases the available torque still more. When you drive the low speed end, the torque available at each successive gear is less. Meanwhile the required torque just to overcome friction keeps adding up at each successive gear. Needless to say, the students are not expected to analyze all this: They should just recognize that the speed reduction gear has a lot more gears and hence a lot more friction.

It is not true that rough surfaces always create more friction than smooth surfaces. A flat board will often slide more easily on a rug (or a brush) than on another board. For instance, summer skiing is done on plastic brush surfaces similar to those used for wiping mud off your feet. Two pieces of clean, smooth, flat glass will not slide over each other easily at all. Friction is a complicated subject. If we didn't have friction, however, how could we walk?

Note that the term "plastic bearing" is introduced in the student handout sheet.

STUDENT HAND-OUT SHEET #10: FINDING THE LOST ENERGY, FRICTION AND HEAT ENERGY

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Leads	4
9	Clear Capsule	1	25	Lg. Wheel	4
10	Oct. Con.	10	28	Lg. Tire	4
12	Sm. Bar Conn.	1	41	Arm Bar	1
14	Coupler	4		Force Spring Scale	
15	Coupler Cap	4		Battery	1

You have built a fan, a car, and a revolving tower.

1. You put a battery in each one. Where was the energy before you turned on the motor? ____________________

2. Where did the energy go when you turned on the motor?

   ____

3. What kind of energy was it? ____________________

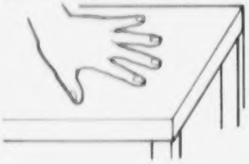
4. After you turned off the motor, was the energy lost?

   ____

5. Rub your hands together hard.

   Are your hands hotter or colder? ____________________

6. Now rub one hand hard against the top of your desk.



   Is the desk top hotter or colder? ____________________

When things rub against each other they stick a little. It takes work to keep up the rubbing. That work turns into heat.

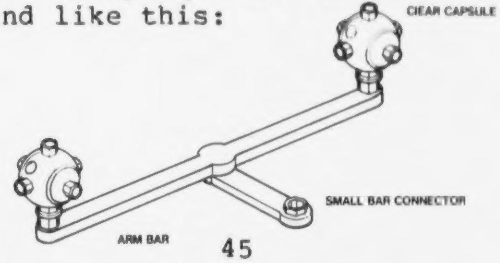
Battery
stored
chemical
energy

electric
current

Motor
electric energy
turns into
motion energy

Fan or Car
motion energy
turns into
heat

The sticking of one thing against another is called friction. Make a merry-go-round like this:



STUDENT HAND-OUT SHEET #10: FINDING THE LOST ENERGY, FRICTION AND HEAT ENERGY (Continued)

Spin the merry-go-round as fast as you can without making it fall over.

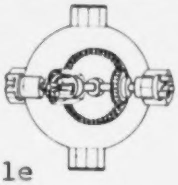
7. Now stop spinning it. What happens? ______________________

8. Did it have energy? ______________________________________

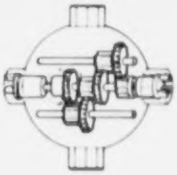
9. Where did the energy go? __________________________________

The lost energy was probably too small to feel. The plastic bearing on the long arm bar does not have much friction. The spinning lever arm did not have much motion energy to lose. But when a real car stops quickly the brakes get hot. When a drill bores a hole in wood, the drill gets so hot you shouldn't touch it.

CROWN WHEEL GEAR CAPSULE



SPEED REDUCTION CAPSULE



Look at the crown wheel gear capsule.

10. Which parts rub against each other?

____

____

Now look at the speed reduction gear capsule

11. Do many more parts rub against each other?

____

12. Is there more friction with the speed reduction gear capsule than with the crown wheel gear capsule? ______________

13. Is it easy to run the crown wheel gear backward? ________

14A. Is it easy to run the speed reduction gear backward? ______

14B. Please explain. ___________________________________

____

Friction robs us of motion energy and turns it into heat. Let's find out if that is always bad.

15. How much pull can your Capsela vehicle produce? Use the force spring scale and find out. ________________

Now take the tires off the drive wheels.

16. How hard can your car pull now? ____________________

17A. Is friction always bad? ____________________________

17B. List places where you need friction	17C. List places where you don't want friction.
____________________	________________________
____________________	________________________
____________________	________________________
____________________	________________________

LESSON 11: SERIES AND ELECTRIC CIRCUITS AND ENERGY SOURCES

OVERVIEW
The students will connect batteries in series and will also connect the lamp and motor in series. They will see again the necessity for having a closed path for the current and will also see the effects of doubling the voltage or of increasing the resistance in a circuit.

PERFORMANCE OBJECTIVE

Your students will be able to follow a wiring diagram to connect simple series circuits. They will also observe the increase in current when the voltage is doubled, and the decrease in current when the lamp and motor are put in series.

PERFORMANCE STANDARD

Each student will be able to make the required wiring connections. Each student will be able to report, orally or in writing, the qualitative results of doubling voltage or of increasing electrical resistance.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Wire Lead	1
20	Lg. Bat. Case	1	24	Lamp	1
21	Sm. Bat. Case	1	Batteries		3

Student Hand-Out Sheet

#11 TEACHERS' NOTES: SERIES AND ELECTRIC CIRCUITS AND ENERGY SOURCES

A major part of the value to be obtained from this lesson is the experience of connecting wires in a closed circuit. It is not easy for some children. Make sure that each of your students can do it.

The "voltage" of a battery is a measure of the energy provided to each electric charge fed into the circuit. In series, the two $1\frac{1}{2}$ volt cells provide 3 volts. If they are connected plus to plus, they provide $1\frac{1}{2} - 1\frac{1}{2} = 0$.

Neither the lamp nor the motor present constant resistance to the current, although in this lesson you can ignore the variable resistance of the lamp. It is very obvious, however, that the motor draws large current when it is starting up (or is laboring or stalled). You can "see" the large current for a moment; it makes the lamp light up. As the motor gets up to normal speed, it presents high resistance. Its high resistance dominates the series circuit so that low current is drawn and the bulb light is very dim.

Why should the motor draw low current when it is running fast? It doesn't need much energy once it's running! (And therefore - or to use another explanation - the motor generates "back voltage" to reduce its input energy.) When the motor starts up, or when it is running gears and wheels, its resistance (back voltage) falls, it draws more current, and so transforms more energy. With this demonstration, you can actually "see" whether or not energy is being used.

Some of your students may be aware of a similar effect with their house or car wiring. If a heavy motor starts up in a house (such as a water pump or air conditioner), the lights may dim for a moment. If you have your car lights on and start the engine, the lights may dim. This opposite effect is caused because the lights and motors are wired in parallel. When the motor draws high current in starting up, the voltage across both motor and lights is momentarily lowered. The motor, however, is drawing more current; a lamp in series with it would get brighter.

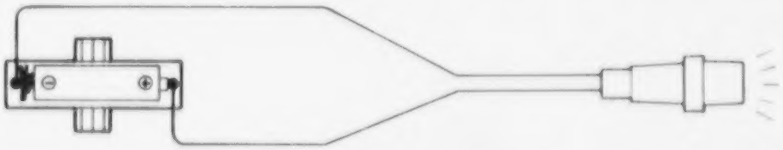
STUDENT HAND-OUT SHEET #11
SERIES AND ELECTRICAL CIRCUITS AND ENERGY SOURCES

MATERIALS: CAPSELA SCIENTIFIC

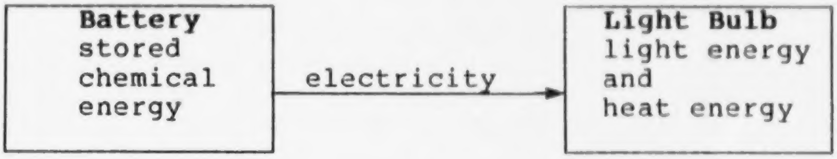
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Wire Lead	1
20	Lg. Bat. Case	1	24	Lamp	1
21	Sm. Bat. Case	1		Batteries	3

In an electric circuit there has to be a closed path from one end of the battery to the other.

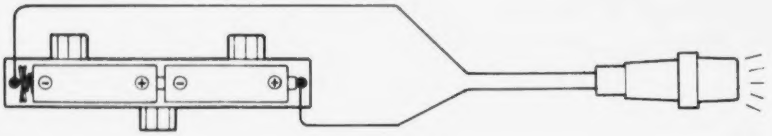
Wire the single battery to the lamp.



Notice how bright the lamp is. The chemical energy from the battery turns into electric energy, and that turns into light and heat energy in the bulb.



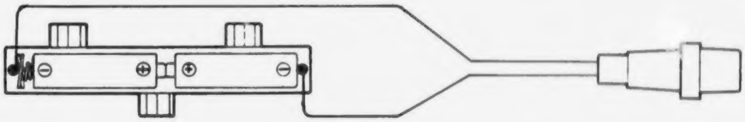
Now, double the energy input! Use two batteries in series.



The negative end of the second battery must be next to the positive end of the first battery. Each battery provides 1½ volts.

1. How many volts do they provide in series? ___________ volts
2. What happens to the lamp when more energy is fed into it?

____



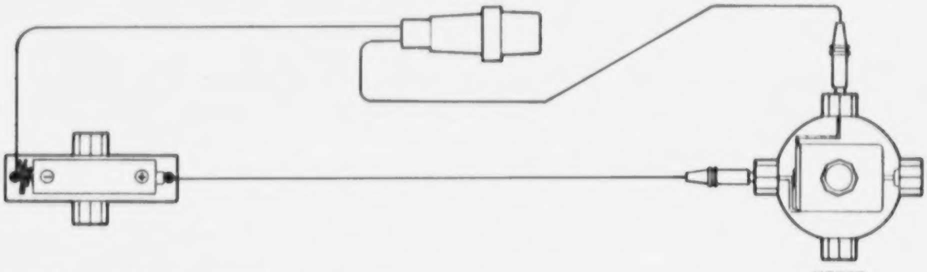
STUDENT HAND-OUT SHEET #11
SERIES AND ELECTRICAL CIRCUITS AND ENERGY SOURCES (Continued)

You can also connect the two batteries in series so that they subtract from each other, instead of adding up. Try it.

3. What happens? ____________________

4. How many volts are produced? ____________________

Now connect one battery in series with the lamp and the motor.



5. Does the motor run? ____________________

6. Does the lamp turn on? ____________________

7. What happens for just a second when you first close the circuit? ____________________

8. What happens to the lamp if you stop the motor by holding the motor gear with your finger, or slow it down? ____________________

9. When the motor is stopped or trying to start up, does it use more current or less? ____________________

10A. Does the light bulb agree with you? ____________________

10B. Please explain ____________________

Now connect the two batteries in series with the lamp and the motor.

11. What happens to the motor and the lamp? ____________________

LESSON 12: ELECTRIC CIRCUITS AND BLINKING LIGHT BEHAVIOR

OVERVIEW

The students continue their exploration of electrical circuitry by using a rotary switch capsule. The students can see the electrical contacts being made and broken, causing a light to turn on and off. They can also see the effects of having the rotary switch turn at high frequency so that the lamp appears to glow steadily.

PERFORMANCE OBJECTIVE

Your students will be able to follow a wiring diagram to connect a switch between the battery and the lamp. They will be able to observe the results of making and breaking electrical contact. They will observe the appearance of a blinking light as the frequency changes.

PERFORMANCE STANDARD

Each student will be able to wire the circuits and assemble the lamp, motor, rotary switch capsule, and other gear capsules. Each student will be able to explain orally or in writing what happens as the frequency of blinking increases.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	10	Oct. Conn	3
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
3	Worm Gear Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	23	Wire Leads	3
6	Rot. Sw. Cap.	1	24	Lamp	1
			Batteries		3

Student Hand-Out Sheet

#12 TEACHERS' NOTES; ELECTRIC CIRCUITS AND BLINKING LIGHT BEHAVIOR

This lesson ties together a number of the preceding ones. It requires skills of connecting electric circuits and of using the gears correctly.

Up until now a circuit has been described simply as a "path" for the current. With the rotary switch the students can see contacts made between pieces of copper. Now is the time to point out that the circuit must consist of things that can carry the current. In most cases, that means metal wires, usually copper. Notice that in the rotary switch, the current doesn't go through the blue plastic.

There can be two reasons why you can't see the lamp blink when the switch is rotating rapidly. (However, you can see that the light is dimmer.) First, the eye has trouble seeing blinking at frequencies higher than about 30 per second. TV and motion picture frames change at about that frequency. The eye-brain merges the pictures into a continuum. Actually, the eye is sensitive to complete on-off blinking up to about 60 times per second, although the response may be one of eye strain rather than actual perception of blinking.

There is a second factor at work here, however. The little bulb in the lamp gives off light because it is heated by the current. It takes a few hundredths of a second for the bulb to heat up or cool down. Therefore, the bulb itself is not completely blinking on and off at frequencies higher than 30 or so per second. (You can actually see the cooling down of a clear 60-watt bulb.)

Some of your students might like to try other combinations of gears to produce intermediate frequencies.

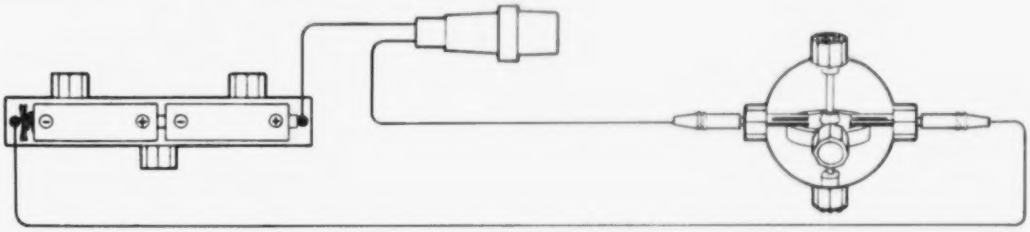
The timing of the light can be done with the aid of the sweep second hand of the classroom clock, if you have one. Alternatively, and better yet, you can teach your students how to count off seconds by saying, "one-thousand-and-one, one-thousand-and-two, etc." With a little practice of saying this while watching a clock or watch, most people can use the method to time short intervals quite accurately.

STUDENT HAND-OUT SHEET #12: ELECTRIC CIRCUITS AND BLINKING LIGHT BEHAVIOR

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	10	Oct. Conn	3
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
3	Worm Gear Cap.	1	21	Sm. Bat. Case	1
4	Cr. Wheel Cap.	1	23	Wire Leads	3
6	Rot. Sw. Cap.	1	24	Lamp	1
			Batteries		3

Connect the rotary switch capsule in series with the double battery and the lamp.



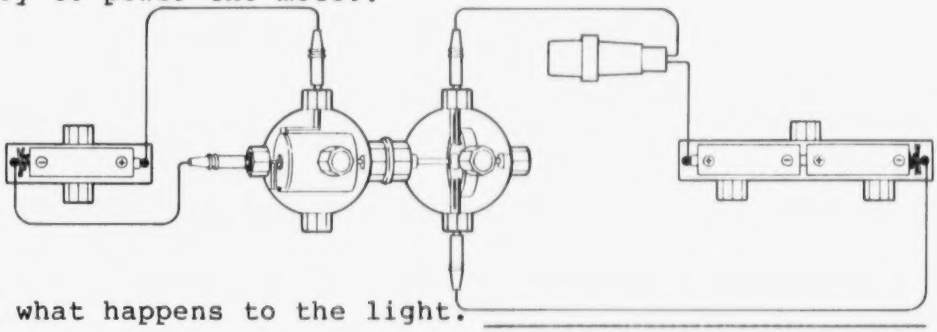
Turn the rotary switch capsule with your fingers so that the lamp turns on and off.

The switch has copper metal fingers that touch a copper metal plate.

1. Describe how the rotary switch turns off the light. ____________

____

Now connect the rotary switch capsule to the motor. Use the single battery to power the motor.



2A. Describe what happens to the light. ____________

____

2B. Can you see it turn on and off? ____________

3. Is the light as bright as when the motor is stopped and the switch is on? ____________

4. Let's slow down the action. Connect the crown gear capsule between motor and rotary switch capsule. (Should the motor drive the little gear or the crown gear in the crown gear capsule?) ____________

STUDENT HAND-OUT SHEET #12:
ELECTRIC CIRCUITS AND BLINKING
LIGHT BEHAVIOR (Continued)

5. Can you see the light blink now? ______________________________

Slow the switch more. Use the speed reduction gear between motor and rotary switch.

6. Can you see the light blink now? ______________________________

7. Does the light stay on longer or shorter than one second?

____

8. How many blinks are there in 10 seconds? ______________________

Slow the action still more! Connect the worm gear in series with the speed reduction gear.

9. Now, how many seconds does the light stay on? _______________

SAVE ENERGY! DON'T LEAVE THE LIGHT ON VERY LONG!

LESSON 13: ENERGY TRANSFORMATION: THE BLINKMOBILE

OVERVIEW

This lesson consolidates the principles and skills learned in the preceding lessons. The students assemble a blinkmobile that requires motor and gears to run, complete with blinking headlight that requires the rotary switch circuit. The blinkmobile makes it apparent how the chemical energy stored in the batteries is transformed into motion energy, heat energy, and light energy.

PERFORMANCE OBJECTIVE

The students will review their previous construction skills and see how they can use these skills to assemble a complicated machine with both mechanical parts and electrical circuitry. They will be able to trace the energy transformations as the machine runs.

PERFORMANCE STANDARD

Each student should successfully assemble a working blinkmobile, either as shown in the student handout sheet or according to an original design. Each student will explain orally or in writing the various transformations of energy, starting with chemcial energy in the batteries. Each student will be able to explain the function of each component.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	14	Coupler	4
2	Spd. Red. Cap.	1	15	Coupler Cap	4
4	Cr. Wheel Cap.	1	20	Lg. Bat. Case	1
5	Int. Gear Cap.	1	21	Sm. Bat. Case	1
6	Rot. Sw. Cap.	1	23	Wire Leads	3
8	Transm. Cap.	1	24	Lamp	1
9	Clear Cap.	1	25	Lg. Wheel	4
10	Oct. Conn.	11	28	Lg. Tire	4
			Batteries		3

Student Hand-Out Sheet

#13 TEACHERS' NOTES: ENERGY TRANSFORMATION: THE BLINKMOBILE

This is a review and consolidation lesson, giving the students a chance to build an interesting blinkmobile. At the same time, the lesson reinforces the skills they have obtained. In particular, they should describe again where the energy comes from and how it is transformed.

The light bulb assembly fits into one of the empty capsules. The students can open the capsule, lay the lamp extending out of one of the openings with the wires sticking out the opposite opening, and then clamp on the other half of the capsule. The two halves of the capsule may not stick together this way, but they will as soon as an octagonal connector is fastened on one of the other openings.

STUDENT HAND-OUT SHEET #13: ENERGY TRANSFORMATION: THE BLINKMOBILE

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	14	Coupler	4
2	Spd. Red. Cap.	1	15	Coupler Cap	4
4	Cr. Wheel Cap.	1	20	Lg. Bat. Case	1
5	Int. Gear Cap.	1	21	Sm. Bat. Case	1
6	Rot. Sw. Cap.	1	23	Wire Leads	3
8	Transm. Cap.	1	24	Lamp	1
9	Clear Cap.	1	25	Lg. Wheel	4
10	Oct. Conn.	11	28	Lg. Tire	4
				Batteries	3

Let's put it all together again. This time you can make a car that moves, with a headlight that blinks.

You can follow the diagram, or design your own blinkmobile.

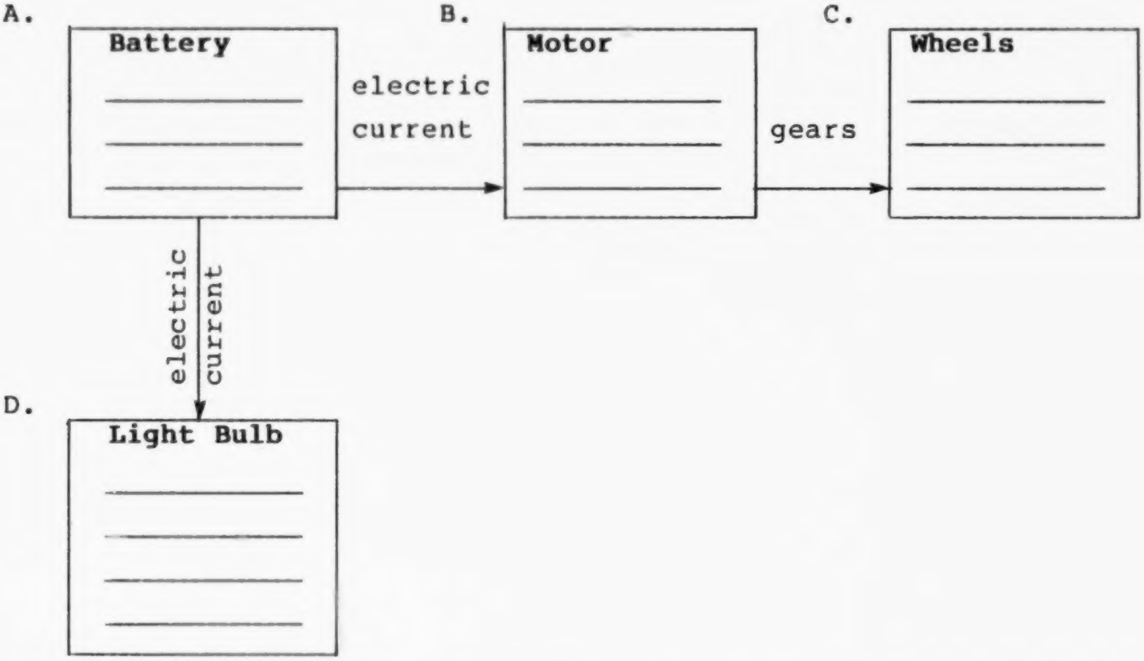
1. What happens if you substitute the internal gear capsule for the transmission capsule? ______________________________

____

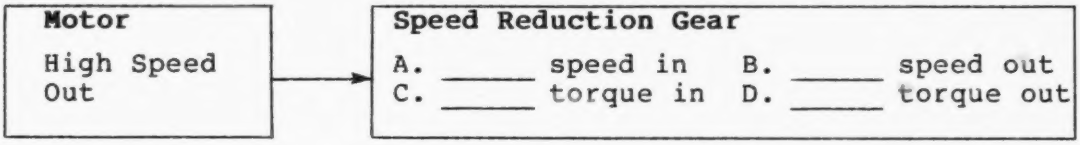
____

The Blinkmobile changes energy in many ways.

2. Fill in the boxes and name the kinds of energy.


A.
Battery
electric current
B.
Motor
gears
C.
Wheels
electric current
D.
Light Bulb

3. Fill in the blanks to explain how a high-speed motor drives a low speed car.

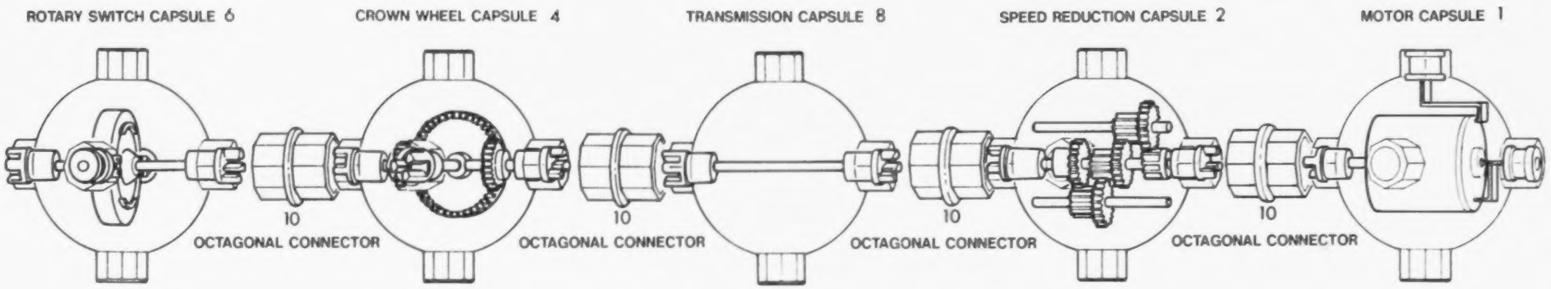

Motor
High Speed Out
Speed Reduction Gear
A. _____ speed in
B. _____ speed out
C. _____ torque in
D. _____ torque out

LESSON 13: THE BLINKMOBILE
"MAKE THE BLINKMOBILE BODY"

MATERIALS: CAPSELA SCIENTIFIC

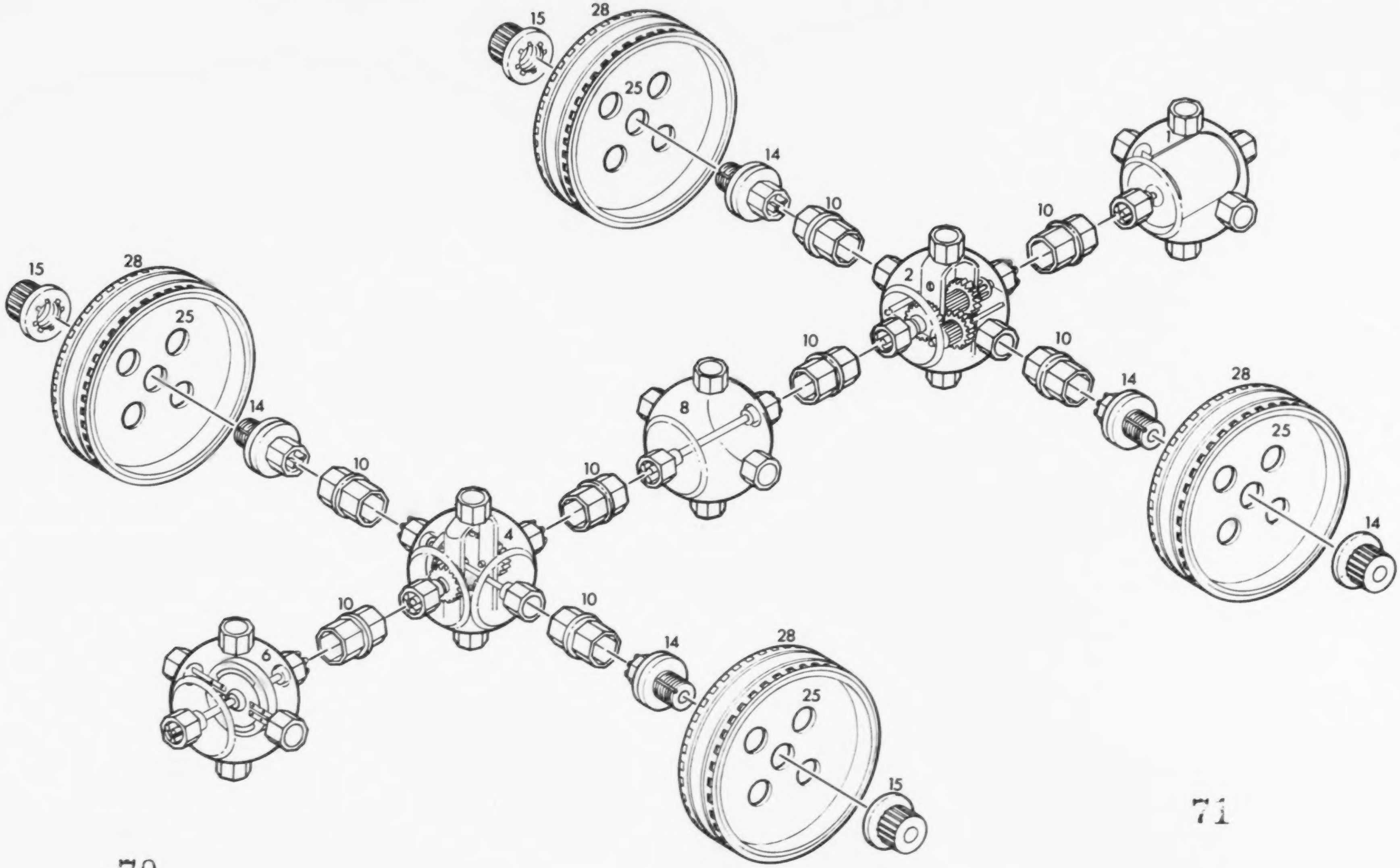
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	14	Coupler	4
2	Spd. Red. Cap.	1	15	Coupler Cap	4
4	Cr. Wheel Cap.	1	20	Lg. Bat. Case	1
5	Int. Gear Cap.	1	21	Sm. Bat. Case	1
6	Rot. Sw. Cap.	1	23	Wire Leads	3
8	Transm. Cap.	1	24	Lamp	1
9	Clear Cap.	1	25	Lg. Wheel	4
10	Oct. Conn.	11	28	Lg. Tire	4
			Batteries		3

57A

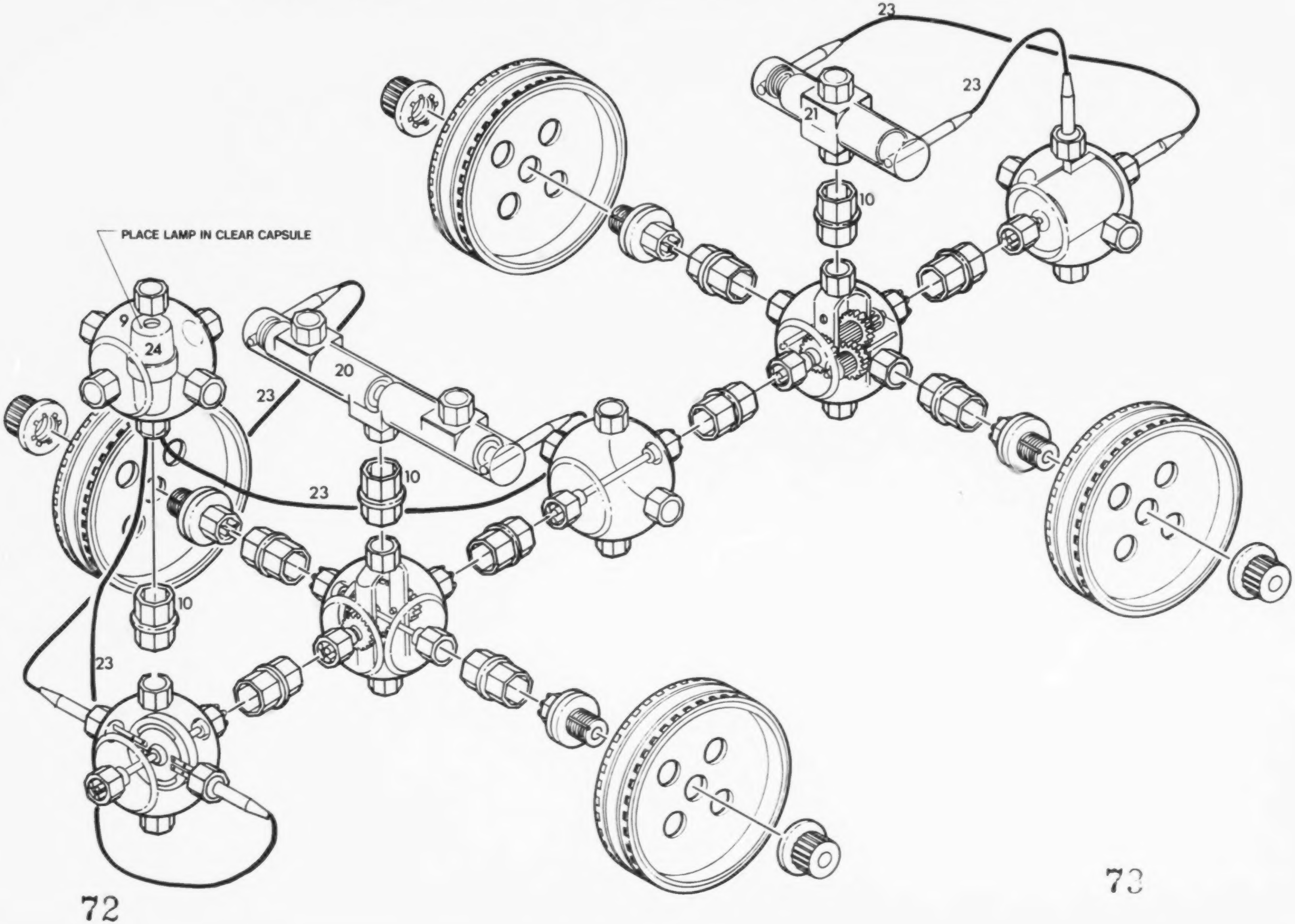

ROTARY SWITCH CAPSULE 6
CROWN WHEEL CAPSULE 4
TRANSMISSION CAPSULE 8
SPEED REDUCTION CAPSULE 2
MOTOR CAPSULE 1
10
OCTAGONAL CONNECTOR
10
OCTAGONAL CONNECTOR
10
OCTAGONAL CONNECTOR
10
OCTAGONAL CONNECTOR

LESSON 13: THE BLINKMOBILE
"ADD THE WHEELS"

57B


15
28
25
14
1
10
10
2
15
28
25
10
10
8
14
14
28
25
10
10
4
14
10
10
6
14
28
25
15

LESSON 13: THE BLINKMOBILE
"COMPLETE THE BLINKMOBILE BY ADDING THE LAMP AND BATTERIES"


23
23
21
10
PLACE LAMP IN CLEAR CAPSULE
9
24
20
23
10
23
10
23

57C

72

73

LESSON 14: CIRCUITRY, ENERGY: THE ROBOT

OVERVIEW

This is partially a review lesson making use of the switch box, but also raises a couple of new questions about some of the components. What happens if you reverse the wire leads going to the switch box. What happens if you use the large battery case instead of the small one. There are also some review questions about going up a hill.

PERFORMANCE OBJECTIVE

Your students will be able to assemble a complex machine making use of both mechanical and electrical parts. They will be able to explore a question in circuitry and see the effect of providing extra energy to the machine.

PERFORMANCE STANDARD

Each student will be able to assemble the robot and test the variations of circuitry and see the effect of providing extra energy to the machine.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	25	Lg. Wheel	3
14	Coupler	3	28	Lg. Tire	2
15	Coupler Cap	3	37	Float	2
20	Lg. Bat. Case	1	Batteries		3

Student Hand-Out Sheet

#14 TEACHERS' NOTES: CIRCUITRY, ENERGY: THE ROBOT

This lesson reinforces the prior learning about circuitry and voltage. The reversing switch says "FWD" (forward) and "REV" (reverse). When you first wire the circuit there is only a 50% chance of those directions being correct. Interchanging wires (either at the battery, or at the motor, or at the switch terminals) will reverse the polarity to the motor, and hence will reverse the motor direction.

The double battery should drive the robot up a steeper hill than the single battery, but probably not a hill twice as steep. There are many other variables involved, primarily the comparative freshness of the batteries.

Remind the students of the method of measuring the grade of a hill (rise/run) from Lesson 9.

STUDENT HAND-OUT SHEET #14: CIRCUITRY, ENERGY: THE ROBOT

MATERIALS: CAPSELA SCIENTIFIC

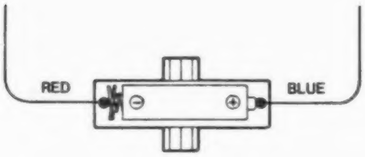
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	25	Lg. Wheel	3
14	Coupler	3	28	Lg. Tire	2
15	Coupler Cap	3	37	Float	2
20	Lg. Bat. Case	1		Batteries	3

Transform Capsela into a robot! The diagrams show you how.

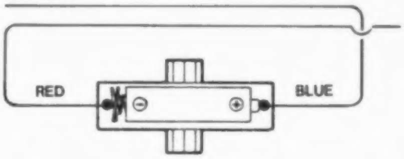
1. Does your robot go forward when the reversing switch says FWD? ____________________

See what happens if you reverse the wires coming from the battery.

If the wire leads are like this:



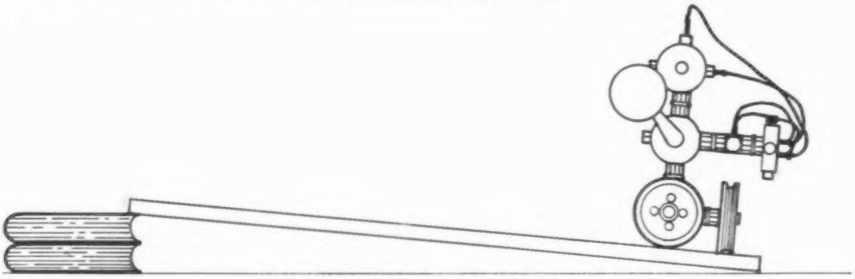
Change them like this:



2. What happens to the direction of the robot when you reverse the wire leads? ____________________

How steep a hill can your robot climb? Make a hill from a long board.

3. What grade can it climb? ________/100



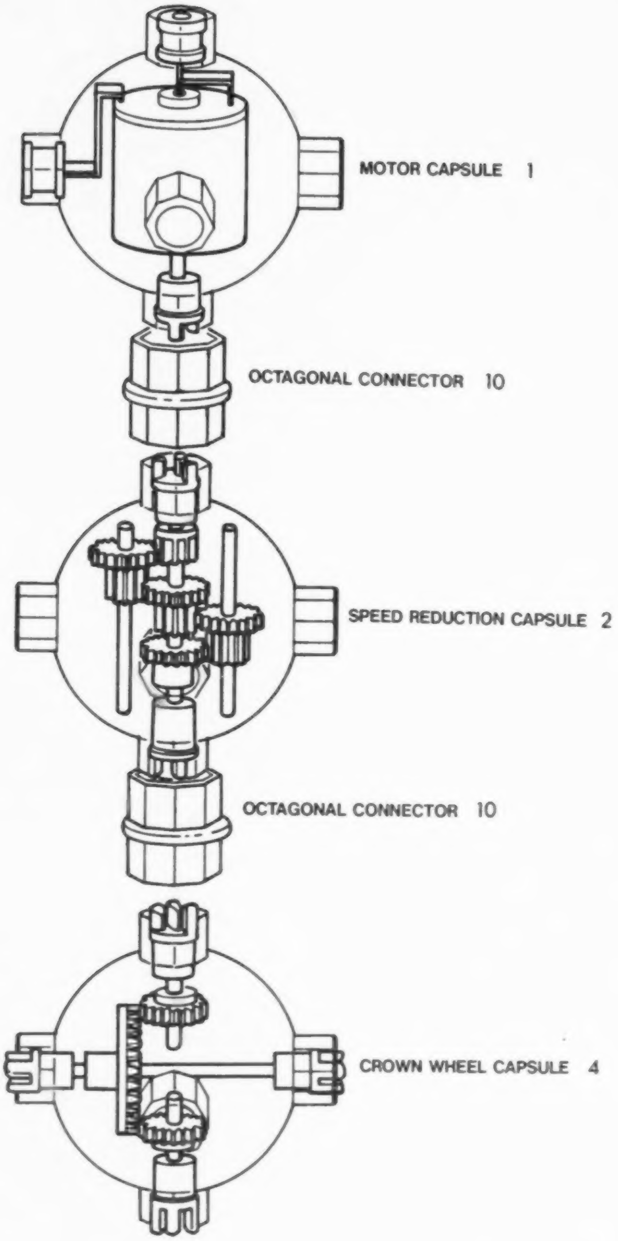
Now put more energy into the motor. Use two batteries in series.

4. How steep a hill can the super-powered robot climb? _____/100

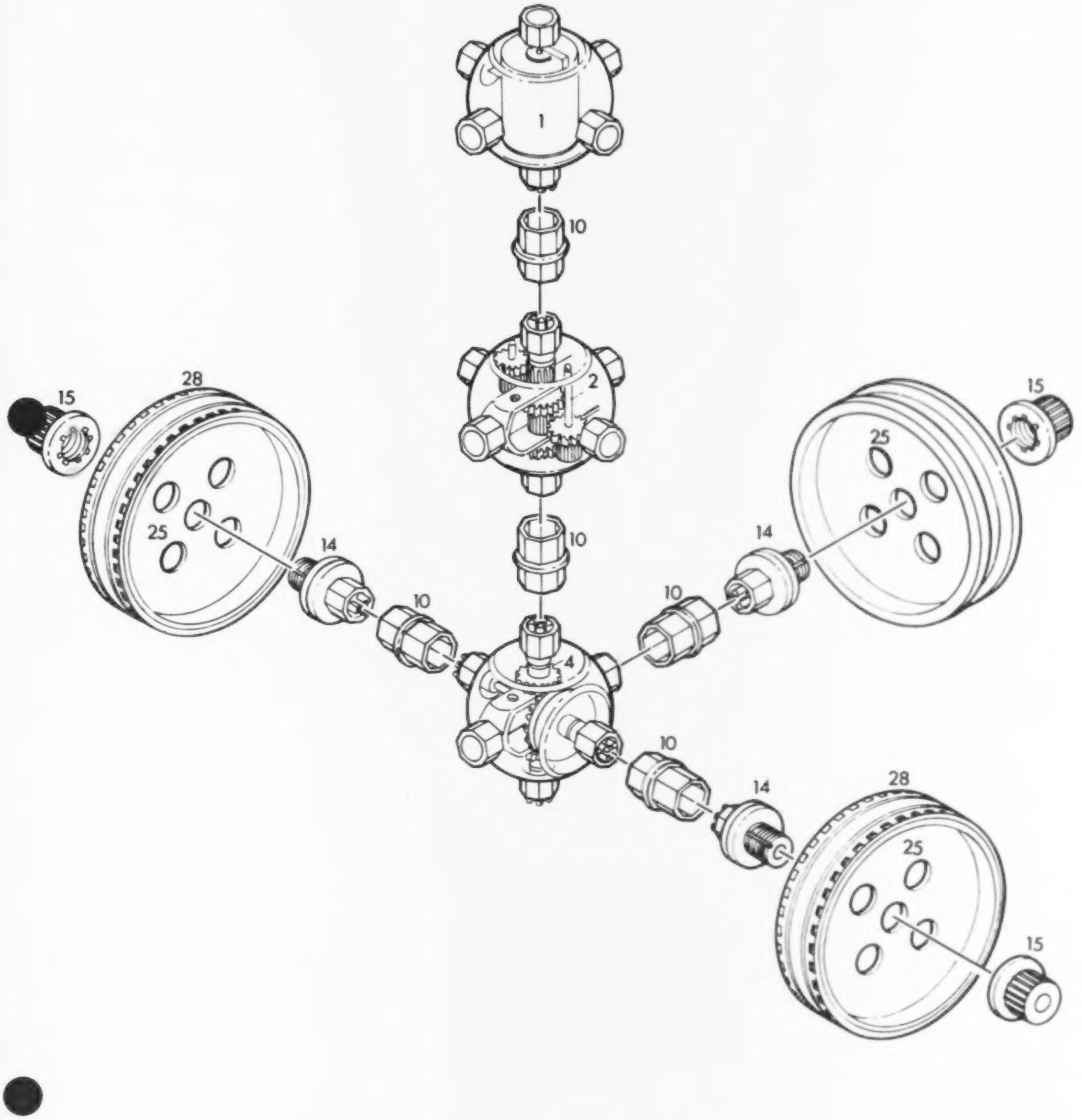
LESSON 14: THE ROBOT
"BUILD THE BODY"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	25	Lg. Wheel	3
14	Coupler	3	28	Lg. Tire	2
15	Coupler Cap	3	37	Float	2
20	Lg. Bat. Case	1		Batteries	3


MOTOR CAPSULE 1
OCTAGONAL CONNECTOR 10
SPEED REDUCTION CAPSULE 2
OCTAGONAL CONNECTOR 10
CROWN WHEEL CAPSULE 4

LESSON 14: THE ROBOT
"ADD THE WHEELS"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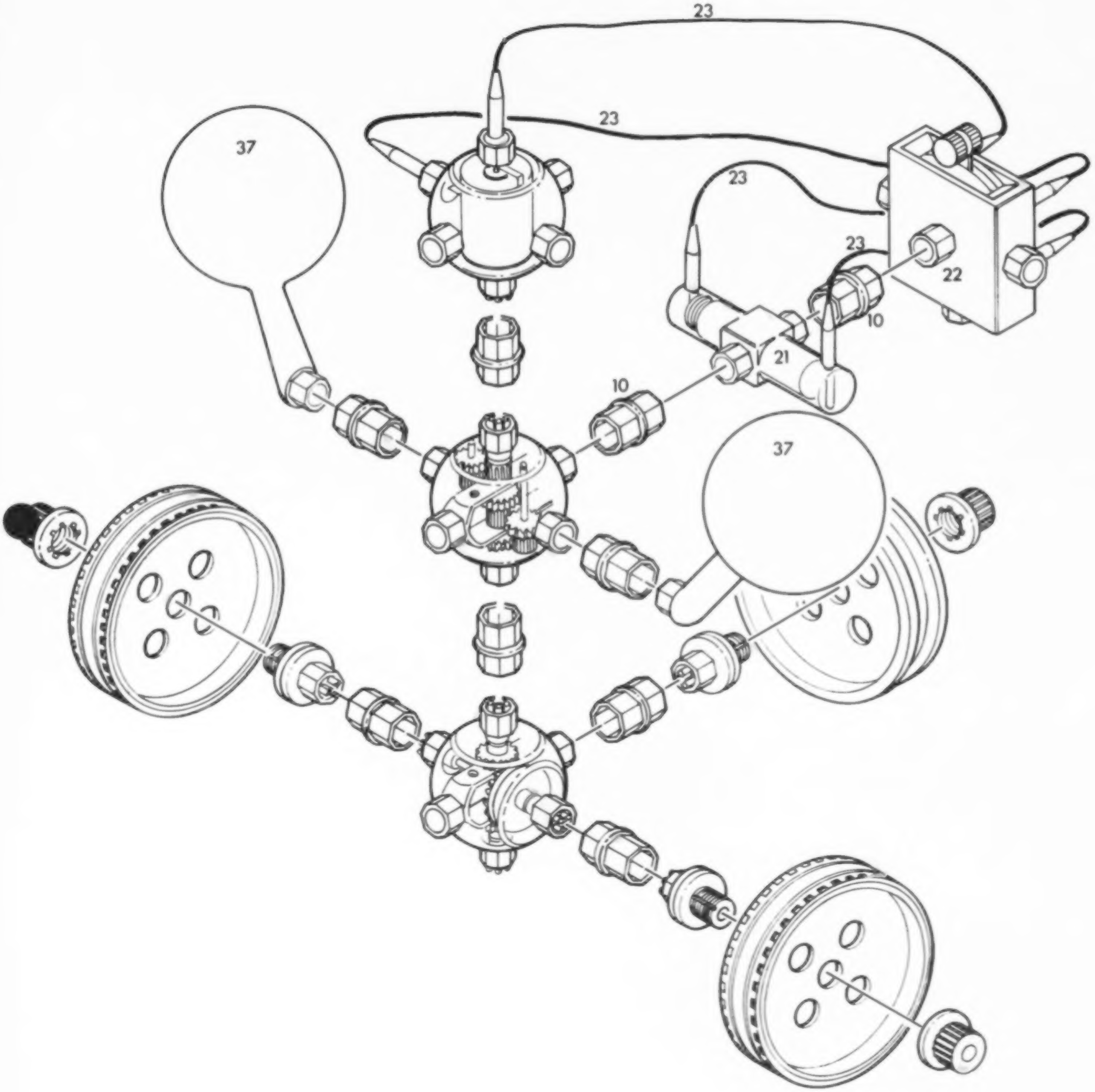
LESSON 14: THE ROBOT
"ADD THE BATTERY, SWITCH BOX, AND ARMS"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LESSON 15: BUOYANCY AND FLUID DISPLACEMENT

OVERVIEW
The students will feel and measure the buoyant effect of objects submerged in water. They will use this information to get a qualitative measure of whether or not objects will float.

PERFORMANCE OBJECTIVE

Your students will be able to relate the buoyant force to the volume of a submerged object, or to the under-water volume of a floating object.

PERFORMANCE STANDARD

Each student will use the force spring scale to measure the buoyant force on one of the gear capsules when it is submerged. Each student will feel the force necessary to shove one of the floats under water. Each student will explain orally or in writing how the buoyant force depends on the volume of the water displaced.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
9	Clear Cap.	1		Jar or Cup Big Enough for Capsule	
37	Float	1			
42	Hook & String Force Spring Scale	1		Jar Big Enough for Yellow Float	

Student Hand-Out Sheet

#15 TEACHERS' NOTES: BUOYANCY AND FLUID DISPLACEMENT

The new word is "buoyancy" or "buoyant." The pronunciation varies slightly with locality, but old salts leave out the u completely. The buoy in a harbor is called a "boy." People who don't live near the water may call it "booee."

The law of buoyancy is called Archimedes' principle: An object in a fluid is buoyed up by a force equal to the weight of the displaced fluid. (The volume of the displaced fluid is equal to the volume of the object.) Incidentally, we are all buoyed up by the weight of the air we displace, but the weight of that air is only about 1/1000 our own weight. Notice that we have not specified this exact law in the student handout sheet. Many high school physics students have trouble understanding the principle quantitatively. However, for the sake of later comprehension, it is useful for students in the elementary grades to have hands-on experience with buoyancy and observe some qualitative effects. If some of your students appear to be capable of more quantitative work, extend the exercise by having them weigh the displaced water.

In order to see easily that water is displaced as an object is submerged, choose a jar with a diameter not much larger than that of the object. In that way the rise of the water level will be more noticeable. If the jar is full to begin with, the overflow will be larger.

Most of the human body consists of water. Consequently most of us have a density about equal to that of water. When we are submerged, we displace a volume of water (equal to our own volume) with a weight about equal to our own weight. Therefore, we float, or almost float. Pre-teen children usually have less fat than adults, are slightly more dense than water, and therefore can't quite float in fresh water. (Salt water is more dense than fresh water, and so the displaced fluid weighs more, and so the buoyant force is greater, and so most people can float easily in salt water.)

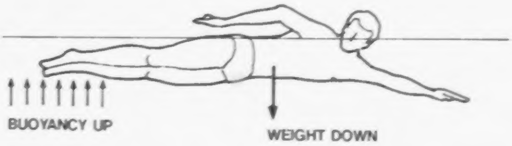
STUDENT HAND-OUT SHEET #15
BUOYANCY AND FLUID DISPLACEMENT

MATERIALS: CAPSELA SCIENTIFIC

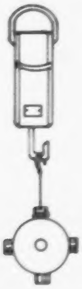
Part #	Description	Pcs	Part #	Description	Pcs
9	Clear Cap.	1		Jar or Cup Big Enough for Capsule	
37	Float	1			
42	Hook & String	1		Jar Big Enough for Yellow Float	
Force Spring Scale					

Buoyancy. That's a strange word! It looks as if the u shouldn't be there. The word sounds like "boy-unsee".

Are you buoyant? You are in the water. It means "lifted up". If you can float, the water buoys you up with a force equal to your weight.

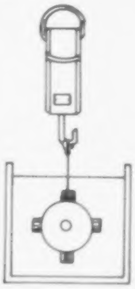


Use the spring scale to weigh a speed reduction gear capsule in the air.



1. The speed reduction capsule weighs __________ in the air.

Now weigh that capsule in water. Make sure all of the air is out of the capsule.



2. The speed reduction capsule weighs ____________ in water.

3. The water buoys up this capsule with a force equal to:

(weight in air) - (weight in water) (Fill in the blanks)

____________________ weight in air

____________________ minus weight in water

____________________ equals buoyant force

4. What happens to the level of the water in the jar when you put in the capsule? ____

The capsule displaces the water, and it has to go somewhere.

5. Fill the jar full of water. Then put in the capsule. What happens to the displaced water? ______________________________

6. Now put the yellow float in a jar. Why doesn't it sink?

____

____

7. Push down on the float until it is all under water. Can you feel the buoyant force? ____________________________________

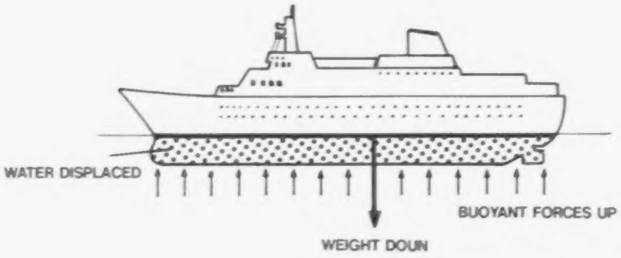
8A. Did you displace more water when you pushed the float under?

____

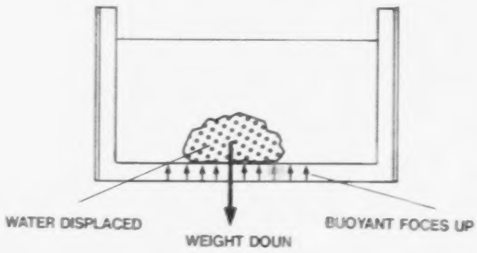
8B. Where did it go? ____

STUDENT HAND-OUT SHEET #15
BUOYANCY AND FLUID DISPLACEMENT (Continued)

The buoyant force up depends on how much water is displaced. A big hollow boat displaces a lot of water, so it floats. A solid stone is heavy and displaces only a small amount of water, so it sinks.


WATER DISPLACED
BUOYANT FORCES UP
WEIGHT DOUN

weight down = buoyant force up


WATER DISPLACED
WEIGHT DOUN
BUOYANT FOCES UP

weight down is greater
than buoyant force up

9. When you are in the water, why do you just about float or just about sink? ______________________________
____

LESSON 16: BUOYANCY, EQUAL AND OPPOSITE FORCES: PROPELLER BOAT

OVERVIEW

The students will use the idea of buoyancy to build a propeller boat machine. Although the main components of motor, battery, switch and propeller are more dense than water, the boat can float because it rests on hollow floats. The buoyant forces on these support the weight of the machine. The boat is driven forward because the propeller drives air backward.

PERFORMANCE OBJECTIVE

Your students will explore and extend their understanding of buoyancy by building the propeller boat. They will consider the reason for its floating in terms of the principle of buoyancy. They will also have their first experience with Newton's third law of motion as they observe the effect of the propeller.

PERFORMANCE STANDARD

Each student will successfully construct the propeller boat and make it move in the water. Each student will explain orally or in writing why the boat can float even though the major components are heavy and would sink by themselves. Each student will also explain orally or in writing why the boat is driven forward by the propeller.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
9	Clear Capsule	3	22	Switch Box	1
10	Oct. Conn.	10	23	Wire Leads	4
14	Coupler	1	33	Propeller	1
15	Coupler Cap	1	37	Floats	4
			Battery		1

Student Hand-Out Sheet

#16 TEACHERS' NOTES: BUOYANCY, EQUAL AND OPPOSITE FORCES: PROPELLER BOAT

It is not intuitively obvious why steel ships can float. Solid steel sinks, but boats are hollow. The boat sinks until the weight of the water displaced equals the total weight of the boat. Then the buoyant force up equals the weight down.

In the case of the propeller boat, the hollow floats provide small weight and lots of volume for water displacement. As the floats sink lower, they displace more and more water until the weight of the water displaced equals the total weight of the floats and all the parts above them.

The geometry of the propeller boat ensures that the switch and motor will be out of the water. Remind the students that the motor and switch should not get wet. It's all right if the battery gets wet, but the students should take it out of its battery case and dry it off afterwards.

The students should draw arrows on their handout sheet diagram showing the action of the buoyant forces on the floats. When they push down on the boat they should be able to see the water level rise on the floats. Whether they can see where the water goes depends on the size of the container. The displaced water must either rise in the container - or overflow.

The propeller action is a nice example of Newton's Third Law, which is usually expressed as, "To every action, there is an equal and opposite reaction." Avoid those words if you can! Action and reaction are archaic words for this phenomenon, meaning something different in Newton's time than they do today. The word now is "force". In any interaction between two objects, the force that the first exerts on the second is equal but opposite to the force that the second exerts on the first. That statement is surely too much for elementary school children. Let them feel the effect in their hands.

Note that rockets don't need air to push against. (In fact, the air gets in the way.) As the high temperature, high pressure region in the rocket expels the gases, the gases exert an equal force on the rocket in the opposite direction.

Your students will see more examples of the application of Newton's Third Law in the following lessons.

STUDENT HAND-OUT SHEET #16: BUOYANCY, EQUAL AND OPPOSITE FORCES: PROPELLER BOAT

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
9	Clear Capsule	3	22	Switch Box	1
10	Oct. Conn.	10	23	Wire Leads	4
14	Coupler	1	33	Propeller	1
15	Coupler Cap	1	37	Floats	4
				Battery	1

1. Does a clear empty capsule float in water? Try it and find out. ______________________________

2. Does the propeller float? ______________________________

3. Do you think a battery can float? ______________________________

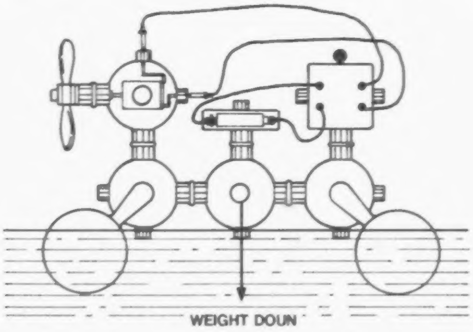
4. Do you think that the motor and switch can float? ______________

Don't try it! If the motor or switch get wet, they may be damaged. In general, you should keep water away from electrical things.

O.K. Let's make a boat out of all those things that don't float.

How? Add some floats! Follow the diagram and build a propeller boat.

5. When you put your boat in the water, what will keep it from sinking? Use arrows and words to show your answer on this diagram:



6. Add more force by pushing gently down on the boat. What happens to the water level on the floats? ______________________

7A. When you shoved down, did you displace more water? ______________

7B. Where did it go? ______________________________

Power the propeller!

8A. Which way does the boat go - left or right? ____________________

Feel the wind from the propeller.

8B. Which way does the air go - left or right? ____________________

STUDENT HAND-OUT SHEET #16:
BUOYANCY, EQUAL AND OPPOSITE
FORCES: PROPELLER BOAT
(Continued)

9A. Which way does the boat go - left or right? ________________

9B. Which way does the wind from the propeller go - left or right? ____

When the propeller forces the air out one way, the air shoves back on the propeller in the opposite direction.

All forces work that way.

10A. When a bat hits a ball forward, what does the ball do to the bat? ____

10B. (Can you feel it in your hands?) ________________________

11. If you press your hand down on your bed, what does the bed do to your hand? ________________________________

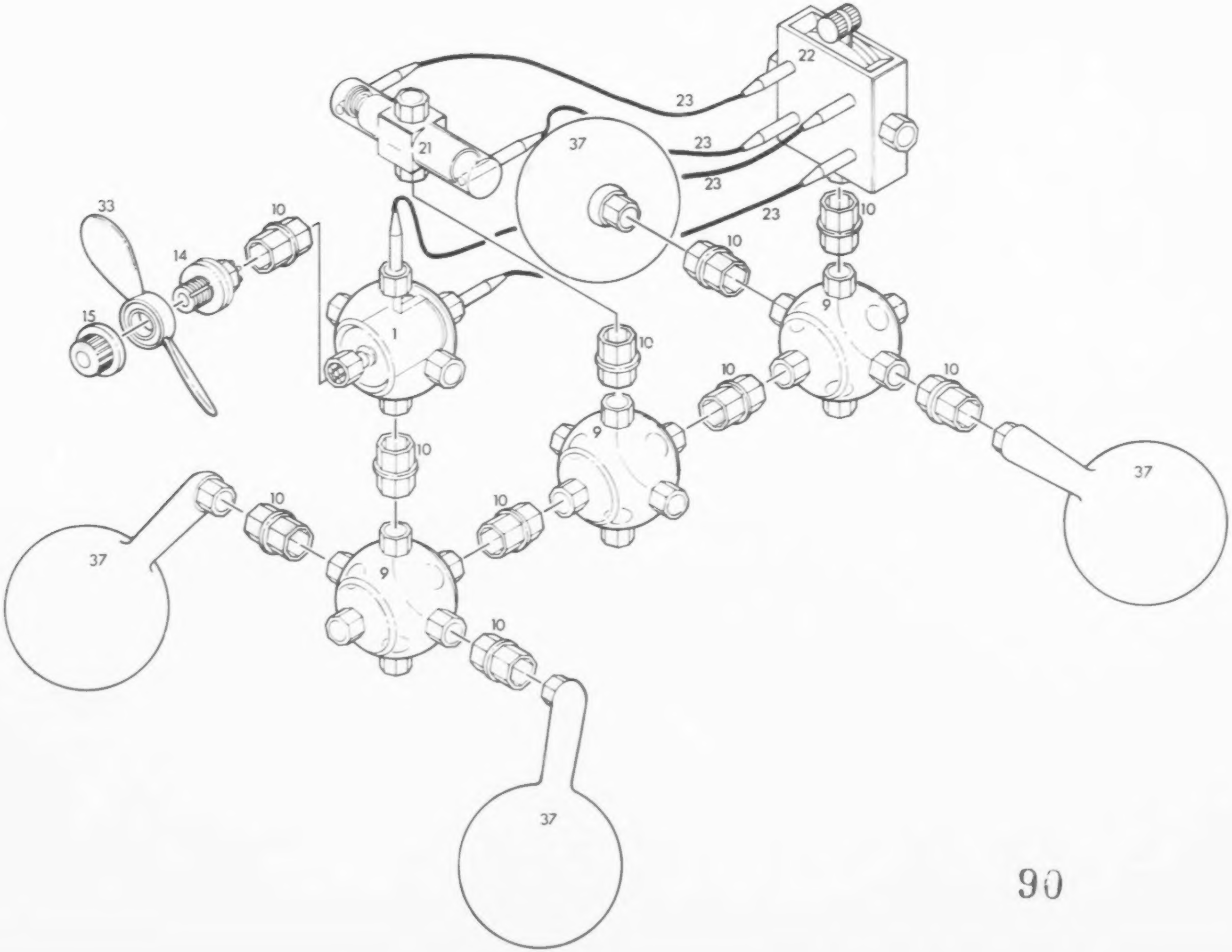
12. If a rocket shoots hot gases down, what do the hot gases do to the rocket? ________________________________

13. Think of another example where something or somebody shoves in one direction, and gets pushed in the opposite direction.
____
____

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
9	Clear Capsule	3	22	Switch Box	1
10	Oct. Conn.	10	23	Wire Leads	4
14	Coupler	1	33	Propeller	1
15	Coupler Cap	1	37	Floats	4
			Battery		1

LESSON 16: PROPELLER BOAT



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LESSON 17: PUMPING WATER: THE WATER PUMP

OVERVIEW

The students will construct a water pump and explore its operation. (In the next lesson the pump will be used as a hydrojet to drive a boat.) The students can observe the motion of the paddle wheels and see how they capture the water and force it up the tube. The students are challenged to alter the design of the machine in order to produce a more efficient pump.

PERFORMANCE OBJECTIVE

Your students will become familiar with another common machine. They will explore the effect on the height of a jet stream of increasing pump speed or changing other variables.

PERFORMANCE STANDARD

Each student will successfully assemble the water pump so that water is driven through the plastic tube. Each student will describe orally or in writing how he or she changed the water pump in order to increase the height of the water jet.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Rd. Cap.	1	21	Sm. Bat. Case	1
3	Worm Gear Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
5	Int. Gear Cap.	1	39	Water Pump	1
8	Trans. Cap.	1	Batteries		3
10	Oct. Conn.	7	Tray for Water or Sink		

Student Hand-Out Sheet

#17 TEACHERS' NOTES: PUMPING WATER: THE WATER PUMP

Effective and efficient pumps are very sophisticated machines. The shape of the blades must be matched to the speed, density, and sometimes the viscosity of the fluid. In this case the flat blades just shove water around in a circular chamber. The faster the blades move, the higher the pressure produced. Consequently, it pays to drive the motor with two fresh batteries in series. The students will discover that one direction of the blades is more effective than the other. (Both directions shove the water out of the tube.)

Students might try substituting the internal gear capsule for the transmission capsule. If the large crown gear in that capsule is driven, higher speed is produced at the output. However, the motor has trouble delivering sufficient power to overcome the extra friction and to provide the consequent increase in torque. Depending on the freshness of the batteries, the jet will not gain extra height this way - but it's a reasonable thing to try.

It takes energy to shove water through the plastic tube. There is a lot of friction near the walls. The energy lost to friction is lost from the motion energy of the water; consequently the water cannot shoot as high against gravity. To avoid this energy loss, use the short length of tube instead of the long one (or cut a one inch short piece off the water pump hose.)

STUDENT HAND-OUT SHEET #17:
PUMPING WATER: THE WATER PUMP

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Rd. Cap.	1	21	Sm. Bat. Case	1
3	Worm Gear Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
5	Int. Gear Cap.	1	39	Water Pump	1
8	Trans. Cap.	1	Batteries		3
10	Oct. Conn.	7	Tray for Water or Sink		

If you had to put out a fire, how could you make the water shoot higher from the hose? You'll have a chance to build a water pump and find out.

Find the water pump, turn the blades with your finger, and see how it works.

Each blade forces water around the circular path and out the hole through the tube.

Follow the diagram, make the pump and try it.

Here's a challenge! Change the water pump machine so that it shoots water higher from the end of the hose. Use any Capsela parts you want - gears, batteries, short hose, long hose.

1. Measure the height of your jet above the end of the hose with a ruler. How many centimeters? ______________________

2. Draw a diagram of your machine. Label all the parts.

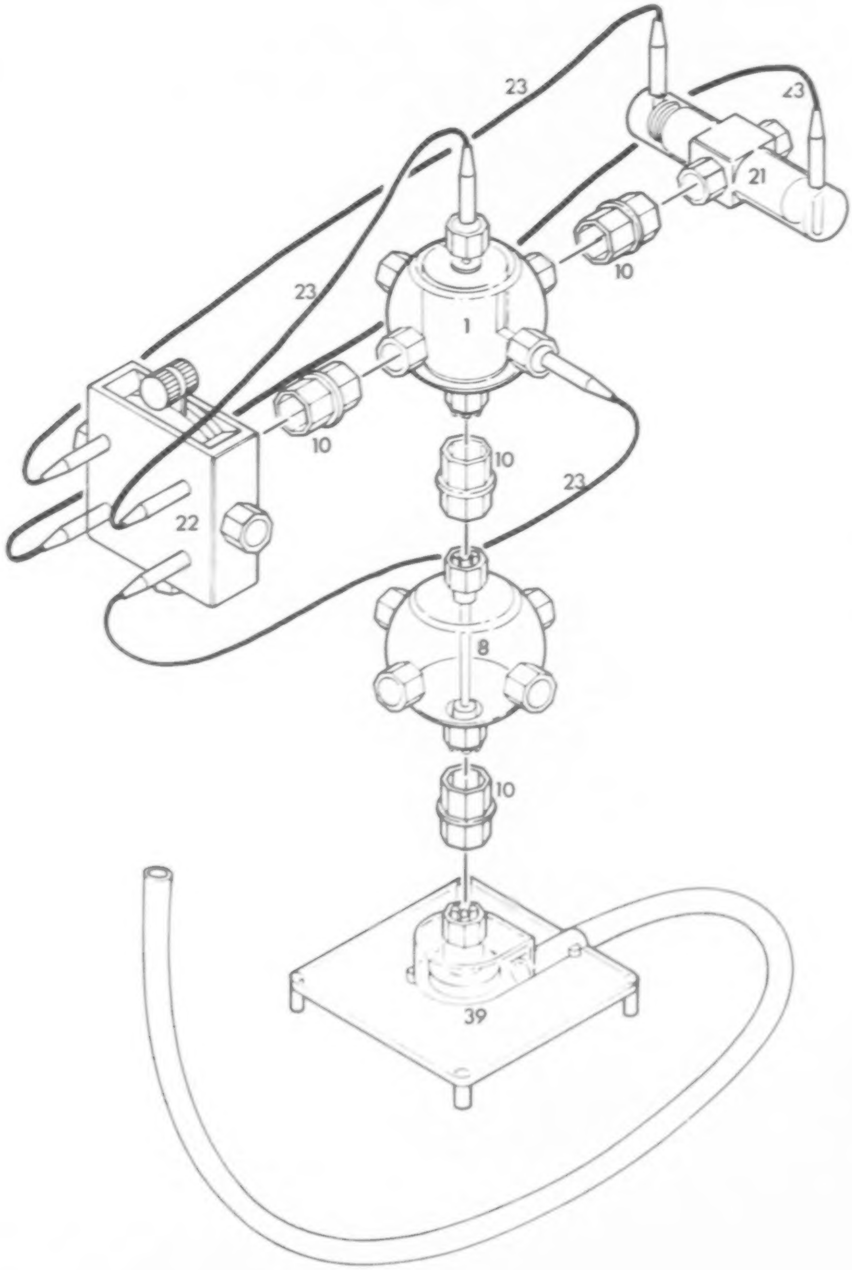
3. Explain why your machine pumps water higher than the first one you built. ____

____

LESSON 17: THE WATER PUMP

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Rd. Cap.	1	21	Sm. Bat. Case	1
3	Worm Gear Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
5	Int. Gear Cap.	1	39	Water Pump	1
8	Trans. Cap.	1		Batteries	3
10	Oct. Conn.	7		Tray for Water or Sink	



LESSON 18: EQUAL AND OPPOSITE FORCES: THE HYDROJET

OVERVIEW
The students learn a new way to propel a boat. They use the water pump, fastened to a boat, to force a water jet underwater. They observe that as the jet goes backward, the boat goes forward. This is another example of Newton's law of equal and opposite forces between two objects.

PERFORMANCE OBJECTIVE

Your students will see another application of Newton's law that if one object exerts force on a second object, the second exerts an equal and opposite force on the first object. The students will be able to drive a Capsela boat with a water jet from the water pump.

PERFORMANCE STANDARD

Each student will construct a water jet driven boat. Each will explain orally or in writing how the backward jet drives the boat forward.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
8	Trans. Cap.	1	23	Wire Leads	4
9	Clear Cap.	2	37	Float	4
10	Oct. Conn.	10	39	Water Pump	1
21	Sm. Bat. Case	1	Battery		1

Student Hand-Out Sheet

#18 TEACHERS' NOTES: EQUAL AND OPPOSITE FORCES: THE HYDROJET

Once again we use Newton's Third Law: water forced out backward generates a forward force on the pump, and therefore on the boat. Note that the action is not caused by the jet pushing against the water. The boat would be driven forward even if the jet were shot out the back into the air. Why not ask one of your more able students to try this and see what happens? A short length of plastic tube could be used to bring the jet out of the water and into the air. See what happens when the jet is pointed at various angles to the backward direction.

When the direction of the fan in the pump is reversed, the blades are not as effective in shooting water out the spout. Therefore, the boat is not shoved forward as effectively.

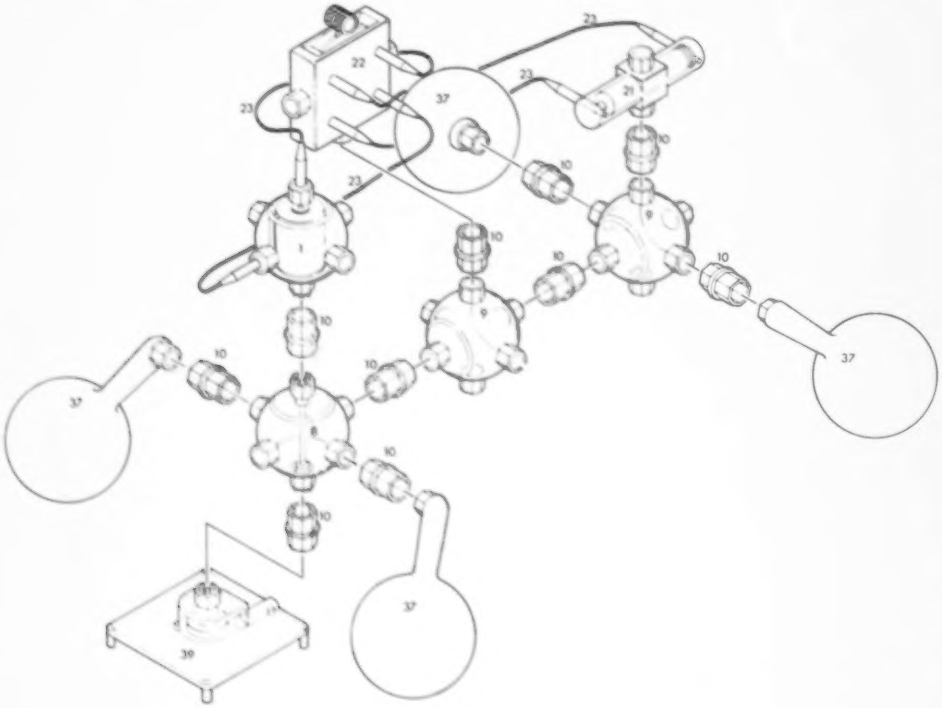
STUDENT HAND-OUT SHEET #18: EQUAL AND OPPOSITE FORCES: THE HYDROJET

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
8	Trans. Cap.	1	23	Wire Leads	4
9	Clear Cap.	2	37	Float	4
10	Oct. Conn.	10	39	Water Pump	1
21	Sm. Bat. Case	1		Battery	1

There's more than one way to power a boat. You can row, sail, use an air propeller, or you can use an underwater jet.

Let's build a hydrojet. Follow the instructions in the diagram. (If you think that you can make a better or faster hydrojet, design your own.)



The pump forces the water jet backward. The water jet must force the boat forward.

1. Explain in your own words how a water pump drives a boat forward. ______________________________
____
____

2. Explain what happens if you reverse the direction of the motor. Try it and see. ______________________
____
____

LESSON 19: EQUAL AND OPPOSITE FORCES, DIFFERENT MEDIUM: MOTOR BOAT

OVERVIEW

The students will find yet another way of propelling a boat. This one is more like the standard "motor boat". It uses an underwater propeller, the same propeller used in the propeller boat. There is an interesting difference between this motor boat and the propeller boat. For best operation of the propeller boat, the propeller (in air) should be driven as fast as possible. When the propeller is underwater, it is necessary to gear down its speed.

PERFORMANCE OBJECTIVE

Your students will construct a boat that is driven by an underwater propeller. They will observe the effect of driving the propeller at different speeds. They will see another application of Newton's Third Law concerning equal and opposite forces.

PERFORMANCE STANDARD

Each student will successfully construct the underwater motor boat. Each student will explain orally or in writing the relationship between the direction of the driven water and the direction of the boat.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	33	Propeller	1
17	Axle Support	1	37	Float	4
18	Long Axle	1	Battery		1

Student Hand-Out Sheet

#19 TEACHERS' NOTES: EQUAL AND OPPOSITE FORCES, DIFFERENT MEDIUM: MOTOR BOAT

Even though a propeller may look something like a giant screw, the propeller does not "screw its way" through the water. Usually the propeller is spinning much faster than would be required by the relatively small forward speed. Instead, the propeller is scooping up water and shooting it backwards. Newton's Third Law applies again. The propeller forces water back; the water being shoved back pushes the propeller (and hence the boat forward).

There is another way of stating Newton's Third Law. The momentum of a closed system must remain constant. The best example of this is seen in the firing of a gun. Before the shot, the gun and bullet are motionless. During the shot, the bullet with small mass, m, shoots out at high velocity, V. Its momentum is the product of its mass and velocity, mV. The heavy gun with mass, M, recoils with small velocity, v. Since the original momentum of the gun-bullet system was zero, the final momentum must be zero. The final momentum is the sum of the momentum of gun and bullet, $mV + Mv = 0$. Therefore, $v_{recoil} = -\frac{m}{M}V$. Notice that the direction of the recoil is opposite (negative) to the direction of the bullet's velocity.

To apply the momentum principle to the action of the propeller, note that the momentum of the wind produced by the air propeller is mV, where m is the mass of the air. The mass of a unit volume of air is only 1/1000 that of the same volume of water. To produce sizeable momentum of air, the propeller must shoot it out at high speed. That doesn't take much torque because the air is light and easily pushed. Such a combination means that the air propeller can be driven by the motor at high speed and low torque.

In the water, however, the propeller requires high torque to push the relatively heavy water. Even though the resulting propeller speed is low, the momentum delivered to the water is still sizeable because the mass of the water is high.

Needless to say, elementary school children will not understand all this in these terms. However, it should be interesting for you to see how much they can intuitively grasp from the actual experiences with these lessons, and how they will express their understanding in their own words.

The motor of a real, high speed motor must shoot backward a lot of high density, high velocity water. That takes a lot of energy and requires a motor that can generate high torque.

STUDENT HAND-OUT SHEET #19:
DIFFERENT MEDIUM: MOTOR BOAT

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	33	Propeller	1
17	Axle Support	1	37	Float	4
18	Long Axle	1		Battery	1

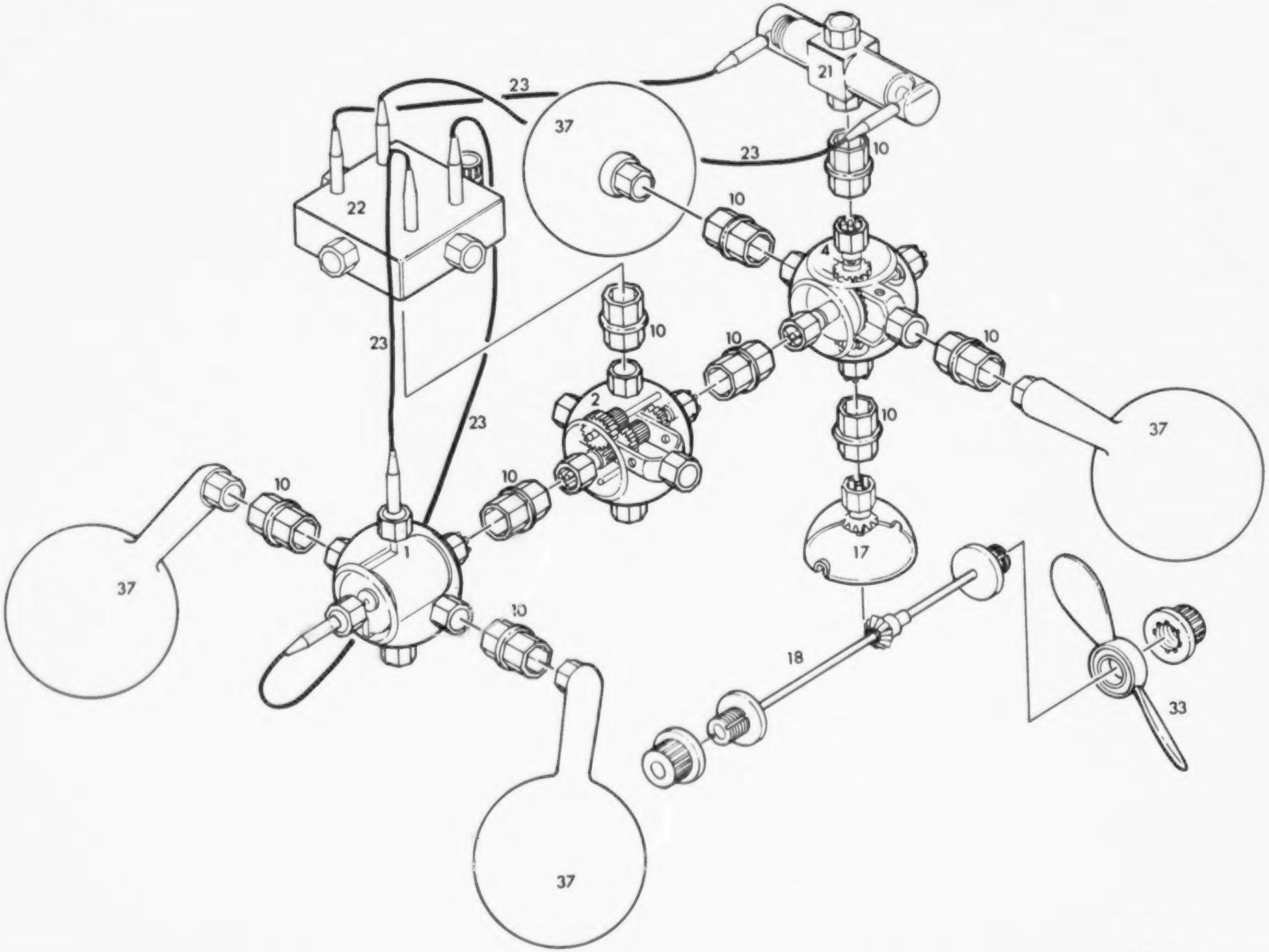
Now you can build a motor boat with a propeller under water. Follow the instructions in the diagram.

1. If you reverse the direction of the propeller (with the switch box), does the direction of the boat reverse? ________
2. If the boat goes forward, what goes backward? ________
3. When you built the air propeller boat did you use the speed reduction gear? ________
4. What happens? ________
5. Why didn't that happen when you made the air boat and the propeller was in the air? ________
6. What do you shoot backward with the air propeller? ________
7. Do you shoot it backward very fast? ________
8. Does it weigh very much compared with water? ________
9. What do you shoot backward with the water propeller? ________
10. Is it travelling very fast? ________
11. Does it weigh very much compared with air? ________
12. With a big, high speed real motor boat, what does the propeller shoot backward? ________
13. Is it travelling very fast? ________
14. Does it weigh very much compared with air? ________
15. Why can the big, high speed motor boat go so fast? Explain in your own words. ________
16. Why does a big, high speed motor boat need a big motor? ________

LESSON 19: THE MOTOR BOAT

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	21	Sm. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
4	Cr. Wheel Cap.	1	23	Wire Leads	4
10	Oct. Conn.	9	33	Propeller	1
17	Axle Support	1	37	Float	4
18	Long Axle	1	Battery		1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LESSON 20: EQUAL AND OPPOSITE FORCES, DIFFERENT SPEED: FERRY BOAT

OVERVIEW

The students will construct another boat propelled by a different mechanism. In this case the backward thrust is provided by paddle wheels. The propulsion principle is basically the same as that of the other boats. Something must be shoved backward in order for the boat to be shoved forward.

PERFORMANCE OBJECTIVE

Your students will construct a ferry boat and explore the effect of driving its paddles at different speeds.

PERFORMANCE STANDARD

Each student will successfully make a ferry boat and observe the effects of driving its paddles at high and low speed. Each student will explain orally or in writing how and why the speed of the paddle wheels affects the speed of the boat.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	2
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
4	Cr. Wheel Cap.	1	21	Sm. Bat. Case	1
5	Int. Gear Cap.	1	22	Switch Box	1
9	Clear Capsule	1	23	Wire Leads	4
10	Oct. Conn.	11	34	Impeller	2
14	Coupler	2	37	Float	4
			Batteries		3

Student Hand-Out Sheet

#20 TEACHERS' NOTES: EQUAL AND OPPOSITE FORCES, DIFFERENT SPEED: FERRY BOAT

The old ferry boats with paddle wheels were not very efficient in shoving water backwards so that the boat would go forward. It was also hard to maintain the giant paddles.

This is the fourth propulsion system that the students have explored for boats. In real paddle wheel boats, a large amount of water is shoved backwards at relatively low speed compared with that produced by a propeller.

This lesson requires students to think about what they have done previously and design a couple of experiments. They might increase the power to the motor by using two batteries. They might change the gear ratio so that the paddles rotate at higher speed (but less torque) or vice versa. Note that the internal gear capsule maintains in-line drive and has a small speed reduction ratio. Of course, the transmission capsule maintains the in-line drive without any change of speed.

STUDENT HAND-OUT SHEET #20:
DIFFERENT SPEED: FERRY BOAT
"THE DELTA QUEEN"

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	2
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
4	Cr. Wheel Cap.	1	21	Sm. Bat. Case	1
5	Int. Gear Cap.	1	22	Switch Box	1
9	Clear Capsule	1	23	Wire Leads	4
10	Oct. Conn.	11	34	Impeller	2
14	Coupler	2	37	Float	4
				Batteries	3

You can build an old fashioned ferry boat with paddle wheels.

Follow the instructions in the diagram.

1. Does the boat go backward as well as it goes forward? ________
2. Does this boat go faster than the one with the underwater propeller? ________________________________
3. Can you make the ferry boat go faster by making the paddle wheels go faster? Figure out two ways you can make them go faster.

A. ____

B. ____

Now try each method and see how it affects the speed.

Result of Method 1 ________________________________

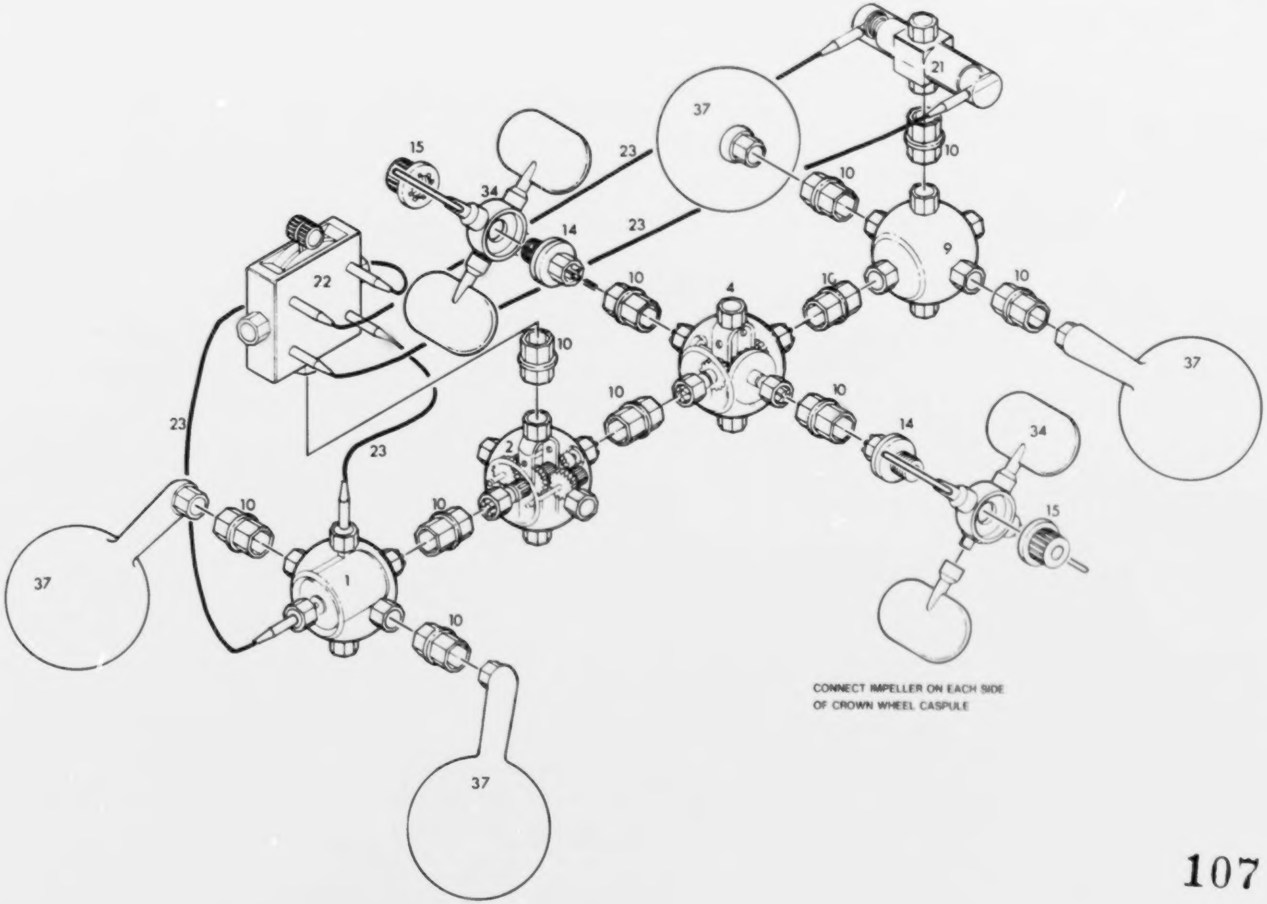
Result of Method 2 ________________________________

4. When the paddle wheel boat goes forward, what is pushed back in the opposite direction? ________________
5. What happens if you twist all eight paddles so that they cut into the water instead of pushing it? ____________
____
6. What happens if you twist only the four paddles on one side so that they cut into the water instead of pushing? ________
____

LESSON 20: THE FERRY BOAT

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	2
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
4	Cr. Wheel Cap.	1	21	Sm. Bat. Case	1
5	Int. Gear Cap.	1	22	Switch Box	1
9	Clear Capsule	1	23	Wire Leads	4
10	Oct. Conn.	11	34	Impeller	2
14	Coupler	2	37	Float	4
			Batteries		3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CONNECT IMPELLER ON EACH SIDE OF CROWN WHEEL CASPULE

LESSON 21: WHEEL-AND-AXLE: THE HOIST

OVERVIEW

The students will build the Capsela hoist which can lift objects from either of two wheel-and-axle drums. (One of these consists of the large wheel without the tire.) One has a larger diameter than the other and so lifts objects much faster, but with less torque. The students will use the force spring scale to measure the lift of each drum. The wheel-and-axle is one of the simple machines.

PERFORMANCE OBJECTIVE

Your students will explore the properties of another simple machine, the wheel-and-axle. They will be able to build the supporting hoist and measure the comparative forces produced by two wheels of different diameters.

PERFORMANCE STANDARD

Each student will successfully build the hoist and lift weights with both wheel-and-axles. They will measure and compare the maximum force that each can exert. Each student will explain orally or in writing the relationship between speed of lift and maximum force exerted.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
2	Spd. Red. Cap.	1	23	Wire Leads	4
4	Cr. Wheel Cap.	1	25	Lg. Wheel	1
5	Int. Gear Cap.	1	37	Float	4
9	Clear Capsule	1	38	Winding Drum	1
10	Oct. Conn.	12	42	Hook & String	2
14	Coupler	1	Battery		1
15	Coupler Cap	1	Force Spring Scale		
21	Sm. Bat. Case	1			

Student Hand-Out Sheet

#21 TEACHER'S NOTES: WHEEL-AND-AXLE: THE HOIST

The students have already seen applications of levers and inclined planes. In this lesson they use the wheel-and-axle, another simple machine. Once again, with a machine you don't get something for nothing. The product of force and distance turned at the rim of the large wheel must be equal to the product of force and distance turned at the small axle. Consequently, with a door knob, our hand exerts a small force through a considerable distance to open the latch. At the axle, a large force is exerted to move the latch bolt, but the distance turned is small.

With the wheel-and-axle used with the Capsela hoist, the gears drive an axle that is common to two wheels. The large one raises objects rapidly, while the small one is very slow. But the small one can lift heavier loads.

The strings should go around the drums several times. It may be necessary to fasten them down with tape. If the capsules are not fastened tightly, the gears may slip before the motor stalls.

Encourage students to substitute other gear combinations. For instance, what happens if the transmission capsule is used instead of the internal gear capsule? Or what happens if the internal gear capsule is reversed so that it increases speed instead of decreasing it?

STUDENT HAND-OUT SHEET #21
WHEEL-AND-AXLE: THE HOIST

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
2	Spd. Red. Cap.	1	23	Wire Leads	4
4	Cr. Wheel Cap.	1	25	Lg. Wheel	1
5	Int. Gear Cap.	1	37	Float	4
9	Clear Capsule	1	38	Winding Drum	1
10	Oct. Conn.	12	42	Hook & String	2
14	Coupler	1		Battery	1
15	Coupler Cap	1		Force Spring Scale	
21	Sm. Bat. Case	1			

Want a lift? Build a hoist! Just follow the instructions in the diagram.

Before you turn on the hoist, look at the way the gears are connected:

Motor	**Speed Reduction**	**Internal Gear**	**Crown Gear**
high speed low torque	high speed in low speed out low torque in high torque out	low speed in lower speed out high torque in higher torque out	lower speed in still lower speed out higher torque in still higher torque out

The final axle on the crown gear turns very slowly but can deliver large torque.

The axle drives two wheels -- one large and one small. Both turn at the same speed, but the outside rim of the big one is moving faster than the outside rim of the small one.

Fasten a long string on each wheel. When the axle turns, the wheels turn, and they will wind up their strings. Put a hook at the end of each string and start lifting things.

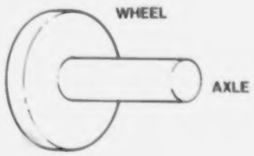
1. Which wheel lifts faster? ______________________________

2. Use the force spring scale to measure the lift of each wheel. Find the force necessary to slow or stop the motor.

A. Force for big wheel ______________________________

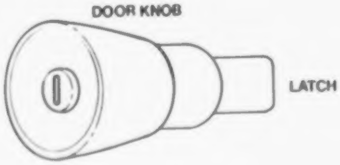
B. Force for small wheel ______________________________

This simple machine on top of the hoist is called a wheel-and-axle. The larger the wheel, the faster the outside rim moves, but the less it can pull.



STUDENT HAND-OUT SHEET #21
WHEEL-AND-AXLE: THE HOIST
(Continued)

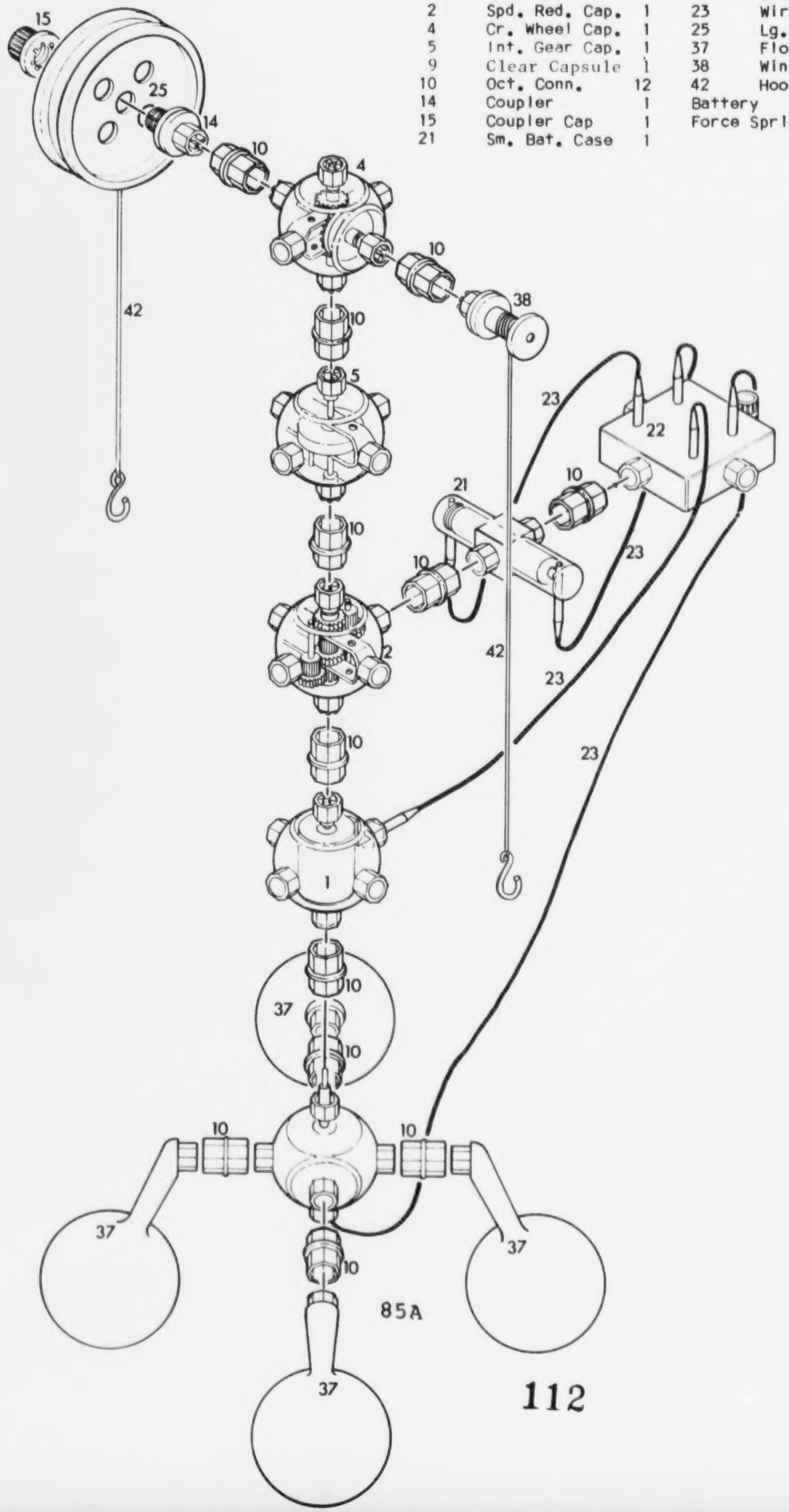
You use a wheel-and-axle when you open most doors. When you turn the door knob, the rim (the wheel) moves quite a distance. The small axle only moves a short distance. But you only have to use a small force on the rim. There's a large force on the axle to move the door latch.



LESSON 21: THE HOIST

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	22	Switch Box	1
2	Spd. Red. Cap.	1	23	Wire Leads	4
4	Cr. Wheel Cap.	1	25	Lg. Wheel	1
5	Int. Gear Cap.	1	37	Float	4
9	Clear Capsule	1	38	Winding Drum	1
10	Oct. Conn.	12	42	Hook & String	2
14	Coupler	1		Battery	1
15	Coupler Cap	1		Force Spring Scale	
21	Sm. Bat. Case	1			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LESSON 22: CHAIN DRIVE, CHAIN-LINKED GEARS, THE WORM GEAR: MINI CYCLE

OVERVIEW

In all the machines studied so far, energy is fed from the motor to some output device either directly or through gears. A chain drive also uses gears, but connects them with a flexible chain that engages the teeth of the gears. Students will recognize this mechanism because they see it on their bikes. In this lesson the students can construct a chain drive and study its operation close-up. They will also study the operation of the worm gear.

PERFORMANCE OBJECTIVE

The students will be able to build a vehicle that uses a chain drive. They can observe the drive mechanism and relate it to the one used on their bicycles. They will be able to analyze the operation of a worm gear.

PERFORMANCE STANDARD

Each student will successfully construct a chain drive vehicle. Each student will explain orally or in writing the way the force is delivered from the motor to drive wheels. Each student will also be able to explain the nature of the worm gear.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
3	Worm Gear Cap.	1	23	Wire Leads	4
10	Oct. Conn.	3	25	Lg. Wheel	1
12	Sm. Bar Conn.	1	27	Sm. Wheel	2
14	Coupler	3	28	Lg. Tire	1
15	Coupler Cap	3	30	Sm. Tire	2
17	Axle Support	1	35	Gear Wheel	2
18	Long Axle	1	36	Chain Links	41
			Batteries		2

Student Hand-Out Sheet

#22 TEACHERS' NOTES: CHAIN DRIVE, CHAIN LINKED GEARS, THE WORM GEAR: MINI CYCLE

It would be useful to have a bicycle in the classroom while the students are working on this project. They can examine the chain drive of the bike and see how the large pedal gear drives the small wheel gear. A single-speed bike is easiest to understand. Avoid a 10-speed; they're too complicated. To study the action, turn the bike upside down.

In the case of the mini-cycle, the gear ratio of the chain drive is just one. The chain is useful because it delivers energy (and torque) from one axle to another one some distance away with a relatively low friction loss. There would be large friction loss in meshing many gears together as shown in the student handout sheet.

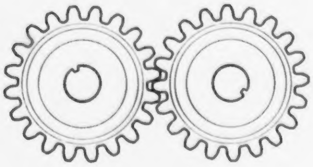
The worm gear drive delivers output torque at right angles to the input. The purpose of the question in the handout sheet is to encourage the students to observe the mechanism closely. It's an interesting variation of gear drive.

STUDENT HAND-OUT SHEET #22
CHAIN DRIVE, CHAIN-LINKED GEARS, THE WORM GEAR: MINI CYCLE
"CHAIN GANG!"

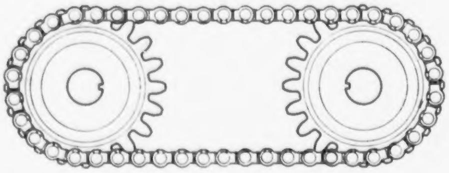
MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
3	Worm Gear Cap.	1	23	Wire Leads	4
10	Oct. Conn.	3	25	Lg. Wheel	1
12	Sm. Bar Conn.	1	27	Sm. Wheel	2
14	Coupler	3	28	Lg. Tire	1
15	Coupler Cap	3	30	Sm. Tire	2
17	Axle Support	1	35	Gear Wheel	2
18	Long Axle	1	36	Chain Links	41
				Batteries	2

Gears don't have to touch in order to move each other. Instead, you can connect them with a chain.



The gears are meshed

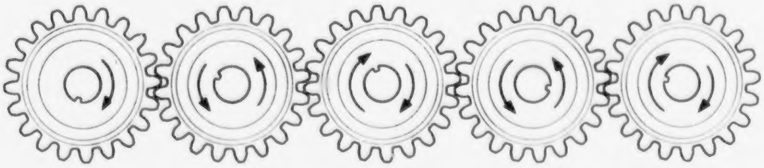


The gears are linked with a chain

Bikes link the pedal gear to the back wheel gear with a chain.

Use your Capsela kit to build a mini-cycle. Just follow the directions in the diagram.

1. If the drive gear on the mini-cycle goes around once, how many times does the wheel gear go around? ____________________
2. Why use a chain drive instead of using many gears like this:



____

3. The Capsela motor spins very fast. The drive wheel on the mini-cycle turns fairly slowly. What gear capsule changes the speed? ____
4. Does the worm gear capsule slow the speed more than the speed reduction capsule? (Measure and find out.) ____________________
5. Why is it called a worm gear? ______________________________
6. There is another big difference in output between the worm gear capsule and the speed reduction capsule. What is it?

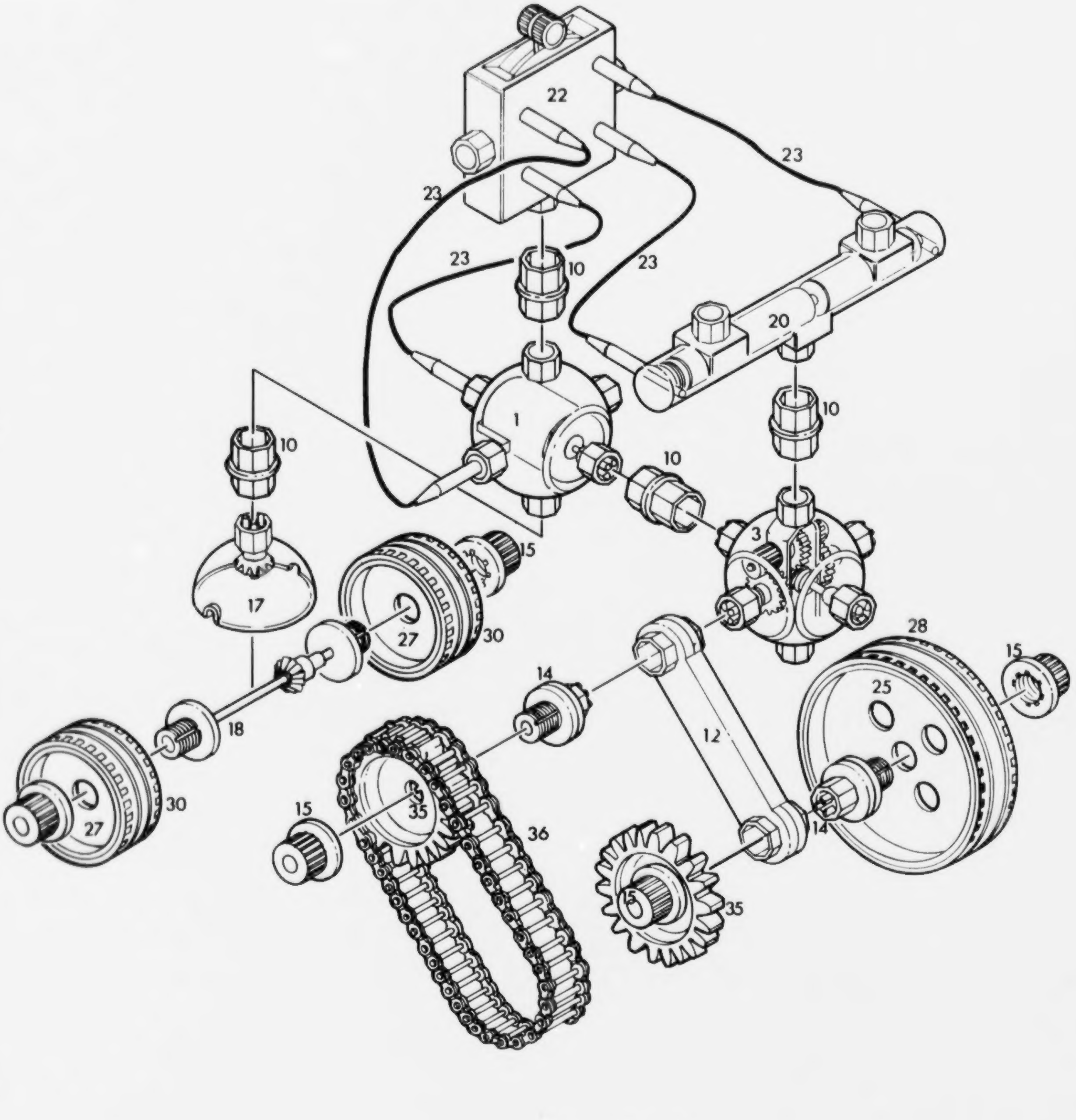
____

____

LESSON #22: THE MINI CYCLE

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	20	Lg. Bat. Case	1
2	Spd. Red. Cap.	1	22	Switch Box	1
3	Worm Gear Cap.	1	23	Wire Leads	4
10	Oct. Conn.	3	25	Lg. Wheel	1
12	Sm. Bar Conn.	1	27	Sm. Wheel	2
14	Coupler	3	28	Lg. Tire	1
15	Coupler Cap	3	30	Sm. Tire	2
17	Axle Support	1	35	Gear Wheel	2
18	Long Axle	1	36	Chain Links	41
				Batteries	2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LESSON 23: SHIFTING GEARS AND THE CLUTCH CAPSULE: THE CRASH CAR

OVERVIEW

The students will explore the properties of a capsule that shifts gears, changing the gear ratio slightly and also reversing the direction of the drive. To observe the reason for these changes, the students must take a detailed look at the operation of the gears.

PERFORMANCE OBJECTIVE

Your students will construct a crash car using a clutch capsule. They will get a better understanding of the action gears.

PERFORMANCE STANDARD

Each student will successfully make a "crash car" whose operation depends on the clutch capsule. Each student will explain orally or in writing how the device changes gear ratios and direction of drive.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
7	Clutch Capsule	1	22	Switch Box	1
8	Trans. Capsule	2	23	Wire Leads	4
9	Clear Capsule	2	25	Lg. Wheel	4
10	Oct. Conn.	12	28	Lg. Tire	4
14	Coupler	4	Batteries		2

Student Hand-Out Sheet

#23 TEACHERS' NOTES: SHIFTING GEARS AND THE CLUTCH CAPSULE: THE CRASH CAR

Understanding the clutch capsule requires a review, and perhaps a new view, of how gears operate. Aside from making an interesting device the students should study the gear shifting mechanism and the direction of gear rotation. Notice that there are two new words that may require some emphasis and explanation: clockwise and counterclockwise.

The car runs at different speeds, forward to backward, because the diameters of the driven gears are different. One complete turn of the drive gear produces a particular number of turns of one gear and a different number of turns of the second gear. Notice that in either case, the device reduces speed. (A small diameter wheel drives a larger diameter wheel.)

To explain why the car reverses direction when the drive gear shifts, the students may use words that refer to the diagram on the handout sheet (in term of Gears 1, 2, 3) or actually show you while holding the capsule.

STUDENT HAND-OUT SHEET #23
SHIFTING GEARS AND THE CLUTCH CAPSULE: THE CRASH CAR

MATERIALS: CAPSELA SCIENTIFIC

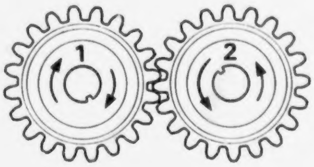
Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
7	Clutch Capsule	1	22	Switch Box	1
8	Trans. Capsule	2	23	Wire Leads	4
9	Clear Capsule	2	25	Lg. Wheel	4
10	Oct. Conn.	12	28	Lg. Tire	4
14	Coupler	4	Batteries		2

Could a real car work with only one set of gears? How would it back up?

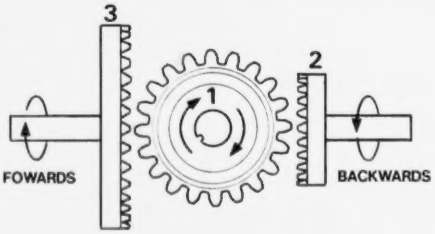
With a real car you must be able to shift gears, from first (low) to second (higher) to third (higher yet), and also reverse (to back up).

You can build a Capsela car that will shift gears. When it hits a wall it will back away. Follow the instructions on the diagram.

Look at the two gears in the diagram below. Suppose Gear 1 turned clockwise; the Gear 2 must turn counterclockwise.



In the clutch capsule, Gear 1 can turn either Gear 2 or Gear 3. Look at the diagram below and also look at the gear shift capsule itself.



1. Explain in your own words why the car runs forward in one gear position and backwards in the other. ____________________
____
____

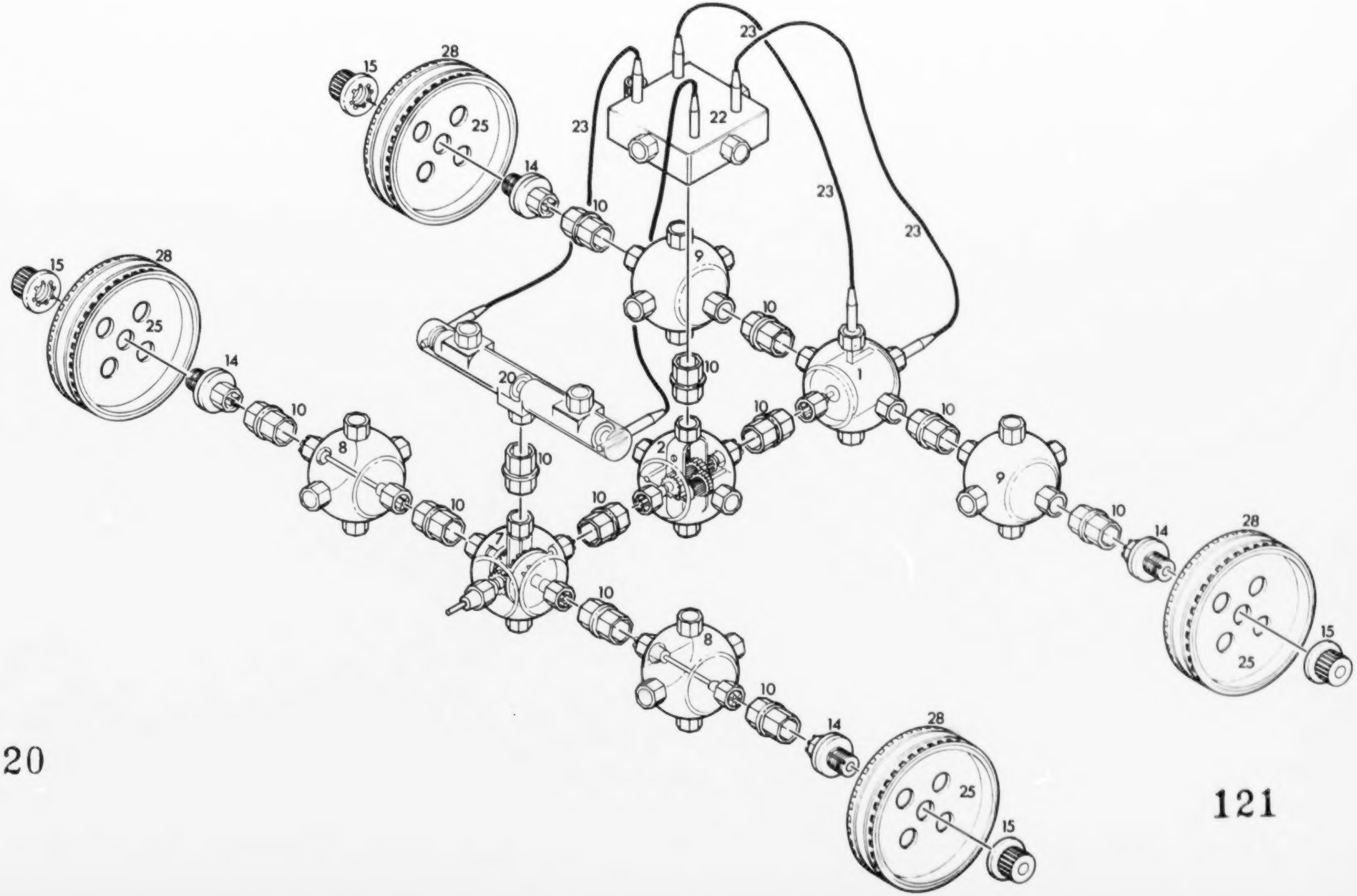
2A. Does the car go as fast in the forward direction as in the backward direction? ____________________

B. Why? ____________________
____
____

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	15	Coupler Cap	4
2	Spd. Red. Cap.	1	20	Lg. Bat. Case	1
7	Clutch Capsule	1	22	Switch Box	1
8	Trans. Capsule	2	23	Wire Leads	4
9	Clear Capsule	2	25	Lg. Wheel	4
10	Oct. Conn.	12	28	Lg. Tire	4
14	Coupler	4	Batteries		2

LESSON 23: THE CRASH CAR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LESSON 24: VACUUM: THE VACUUM CLEANER

OVERVIEW

This review lesson introduces another Capsela component, an enclosed or shrouded fan. The students will observe how the low pressure region created by the fan leads to a slight breeze that sweeps dust and bits of paper into the "vacuum" chamber. By reversing the switch the students can reverse the direction of the fan and discover that it works well only in one direction. They can then observe the reason for this by turning the fan slowly and studying its action.

PERFORMANCE OBJECTIVE

Your students will construct a "vacuum cleaner" and study the action of a shrouded fan.

PERFORMANCE STANDARD

Each student will successfully make and operate the "vacuum cleaner." Each student will be able to explain orally or in writing why the motion of the fan produces an internal low pressure which draws air into the entrance.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Wire Leads	4
9	Clear Capsule	1	44	Closure Cap	4
10	Oct. Conn.	9	45	Fan	1
20	Lg. Bat. Case	1	46	Inlet Port	1
22	Switch Box	1		Tissue or Gauze	
				Batteries	2

Student Hand-Out Sheet

#24 TEACHERS' NOTES: VACUUM: THE VACUUM CLEANER

"Vacuum" means empty of everything -- no air. Of course, a vacuum cleaner produces only a partial vacuum. The particular shrouded fan in this lesson creates a breeze from input to output. That breeze is sufficient to draw dust into the chamber.

The students can produce a larger partial vacuum by sucking on a straw. The liquid rises in the straw because the air pressure on the liquid surface forces the liquid up the straw when a partial vacuum is created inside.

The plastic top of the shrouded fan shows the preferred direction of rotation for producing a breeze. As the students will discover, the other direction also works, though not so well. The off-center housing is supposed to whirl the air out the curved track, but the fittings are loose enough so that the "wrong" direction works a little bit.

STUDENT HAND-OUT SHEET #24: VACUUM: THE VACUUM CLEANER

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Wire Leads	4
9	Clear Capsule	1	44	Closure Cap	4
10	Oct. Conn.	9	45	Fan	1
20	Lg. Bat. Case	1	46	Inlet Port	1
22	Switch Box	1		Tissue or Gauze	
				Batteries	2

It's time to clean up! You can make a vacuum cleaner to help.

Just follow the directions in the diagram.

Your vacuum cleaner can pick up dust or small pieces of tissue paper. Can you feel the air going in and coming out? Try feeling it with your fingers or by holding a strip of tissue paper nearby.

1. Try reversing the direction of the motor. Does the vacuum cleaner work? ______________________________

2. Look at the fan blades. Turn them slowly, first in one direction and then the other. Explain in your own words why the vacuum cleaner works better in one direction than the other. ______________________________
____
____
____

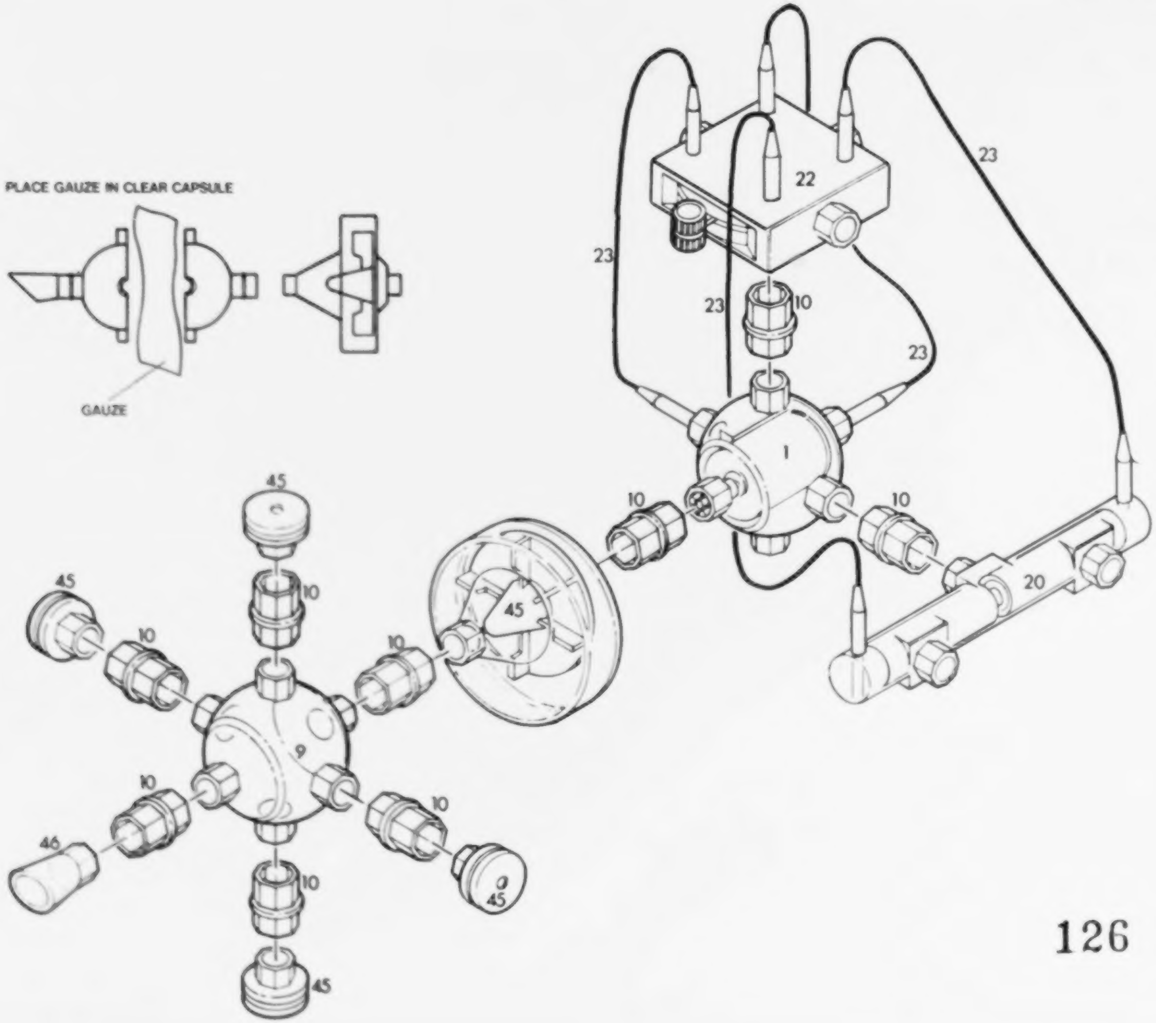
3A. Can you produce a vacuum without a machine? ____________

B. How? ______________________________

LESSON 24: THE VACUUM CLEANER

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	23	Wire Leads	4
9	Clear Capsule	1	44	Closure Cap	4
10	Oct. Conn.	9	45	Fan	1
20	Lg. Bat. Case	1	46	Inlet Port	1
22	Switch Box	1		Tissue or Gauze	
				Batteries	2


PLACE GAUZE IN CLEAR CAPSULE
GAUZE
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45

94A

LESSON 25: CIRCUITRY, FORCES: PROPELLER CAR

OVERVIEW

This lesson produces an interesting car propelled by an air propeller. The lesson can serve as a review of circuitry. The students will find that when the motor is powered by only one battery, the car barely moves. With two batteries in series the car moves easily, and with three batteries in series the propeller races and the car moves rapidly. Part of the student exercise consists of learning to connect the batteries correctly in series.

PERFORMANCE OBJECTIVE

Your students will combine the design of a car and the air propeller boat to make a car driven by an air stream. In studying the behavior of this machine, they will review how to wire batteries in series.

PERFORMANCE STANDARD

Each student will be able to make the propeller car, and wire several combinations of voltage supply. Each student will be able to demonstrate how to wire batteries in series.

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	18	Long Axle	2
9	Clear Capsule	1	20	Lg. Bat. Case	1
10	Oct. Conn.	7	21	Sm. Bat. Case	1
14	Coupler	1	22	Switch Box	1
15	Coupler Cap	1	23	Wire Leads	5
17	Axle Support	2	25	Lg. Wheel	4
			33	Propeller	1
			Batteries		3

Student Hand-Out Sheet

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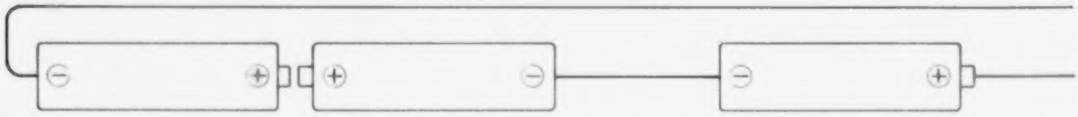
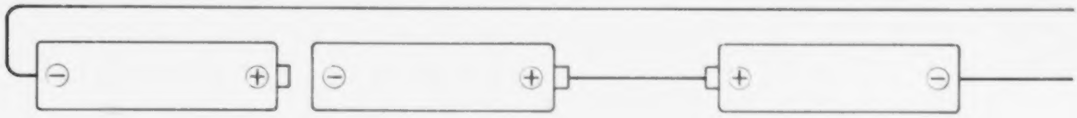
#25 TEACHERS' NOTES: CIRCUITRY, FORCES: PROPELLER CAR

The propeller car amuses most people more than the air propeller boat or a car driven by its wheels. It's surprising to see wind used to propel a land vehicle.

For maximum propeller speed, the three batteries should be wired in series: + to - to + to - to + to -, as shown in the diagram on the handout sheet. The three 1-1/2 volt batteries thus add to 4-1/2 volts. Of course, you can get 3 volts by using just the double battery or 1-1/2 volts by using just the single battery. However, you can also get 1-1/2 volts by wiring all three batteries in series like this:



or better yet, like this:



In each case, two of the batteries cancel each other, yielding only the voltage of the third one.

STUDENT HAND-OUT SHEET #25: CIRCUITRY, FORCES: PROPELLER CAR

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	18	Long Axle	2
9	Clear Capsule	1	20	Lg. Bat. Case	1
10	Oct. Conn.	7	21	Sm. Bat. Case	1
14	Coupler	1	22	Switch Box	1
15	Coupler Cap	1	23	Wire Leads	5
17	Axle Support	2	25	Lg. Wheel	4
			33	Propeller	1
			Batteries		3

Did you ever see a small airplane "taxi" at an airport? The plane rolls along the runway, but its wheels don't make it move. Its propeller spins, shoving air backwards which forces the plane forward.

You can make a Capsela car driven by a propeller. Just follow the directions in the diagram.

1. First, try powering the motor with just one battery.
   A. Does the car move? ______________________________
   B. Is it fast? ______________________________

2. Now power the motor with two batteries in series. Does the car move faster? ______________________________

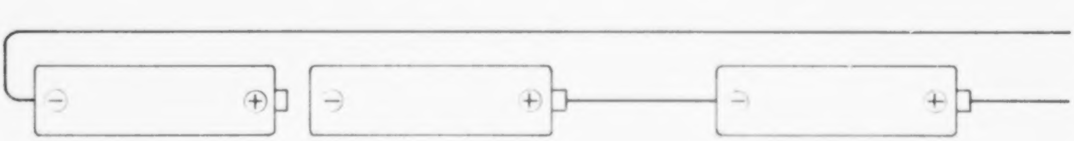
3. Maybe three batteries in series will make the propeller spin faster which will make the car go faster. Try it and see.

   Is it faster? ______________________________

4. Use the reversing switch to make the car go forward and backward. Feel the wind from the propeller.
   A. If the car goes forward, what is the wind direction? __________
   B. If the car goes backward, what is the wind direction? __________

Here's a challenge! Wire all three batteries in series but produce only 1-1/2 volts. Can you do it? Try your arrangement on the motor to make sure the car moves slowly.

Here's the way the batteries look when they are wired in series and produce 4-1/2 volts.

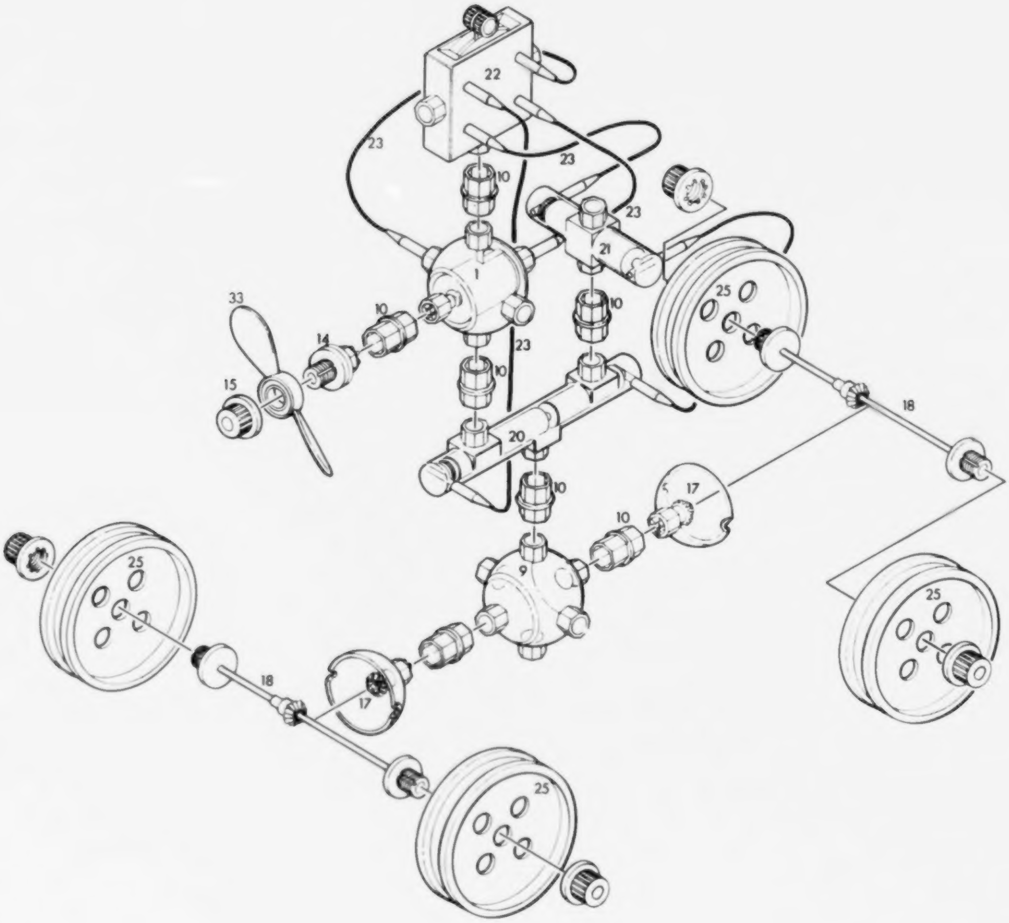


Show how the batteries look when you wire them all in series and produce only 1-1/2 volts.

LESSON #25: THE PROPELLER CAR

MATERIALS: CAPSELA SCIENTIFIC

Part #	Description	Pcs	Part #	Description	Pcs
1	Motor	1	18	Long Axle	2
9	Clear Capsule	1	20	Lg. Bat. Case	1
10	Oct. Conn.	7	21	Sm. Bat. Case	1
14	Coupler	1	22	Switch Box	1
15	Coupler Cap	1	23	Wire Leads	5
17	Axle Support	2	25	Lg. Wheel	4
			33	Propeller	1
			Batteries		3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STUDENT HAND-OUT SHEET ANSWERS

LESSON 1

1. Yes
2. Yes
3. Yes
4. No
5. Into the air
6. From food

LESSON 2

1. Not much energy
2. Yes
3. It takes work to make a battery

LESSON 3

1. Lamp goes out
2. Lamp goes out again
3. Lamp goes on
4. Propeller turns in opposite direction
5. Yes
6. Yes
7. Turns to heat

LESSON 4

1. Yes
2. Yes
3. Yes
4. It slows down
5. Harder
6. No
7. Nothing
8. It looks like a crown
9. Slower
10. Slower
11. No
12. Slower
13. Just barely

14A. 2
14B. 48 (approximately)
14C. 23
14D. 3
15. The worm gear
16A. The crown wheel
16B. Two times
17. The worm gear
18. It moves very slowly

LESSON 5

1A. Yes
1B. Very slowly or not at all (dependent on floor surface and battery power)
2. Speed reduction
3. Yes
4. Yes
5. Yes

LESSON 6

1. Yes
2. Have the large crown gear face the side instead of the top
3. Tower will not move in either direction due to friction

LESSON 7

1. Open
2. Open
3. Open
4. It slows down
5. No

LESSON 8

1. Open
2. No
3. No
4. Yes
5. Long

LESSON 9

1. Open (Take actual height measurement)
2. Motion energy

3A. No
3B. If you use a small force you must do it through a large distance. Or, if you use a large force you must do it through a short distance.

LESSON 10

1. Chemical energy in the battery
2. Into the wheels
3. Motion energy
4. Apparently it disappears
5. Hotter
6. Hotter
7. It slows to a stop
8. Yes
9. Into heat
10. The input and output gears
11. Yes
12. More
13. No
14A. No
14B. More parts create more friction
15. Open (Take actual measurement)
16. It's going to be less
17A. No
17B. Brakes - Tires - Shoes
17C. Skates - Bearings - Sleds

LESSON 11

1. 3 Volts
2. Lamp brightens
3. Lamp does not light
4. Zero
5. Yes
6. Yes, but it's dim
7. The lamp brightens to normal
8. Again, the lamp brightens to normal
9. More
10A. Yes
10B. The more current, the brighter
11. Motor runs faster and lamp is brighter

LESSON 12

1. The copper metal fingers do not touch the copper plate
2A. It remains on
2B. No
3. No, the light is dim
4. The little gear
5. Yes
6. Yes, but more pronounced
7. Shorter
8. Approximately 30 blinks
9 About 4 seconds

LESSON 13

1. Either it goes faster or slower
2A. Stored chemical energy
2B. Turns electric energy into motion energy
2C. Motion
2D. Light and heat
3A. High
3B. Low
3C. Low
3D. High

LESSON 14

1. Yes or No
2. It moves in the opposite direction
3. Take actual measurement
4. Take actual measurement

LESSON 15

1. Take actual measurement
2. It will weigh less
3. Fill in the measurements and do the arithmetic
4. It rises
5. It spills
6. It's lighter and larger
7. Yes
8A. Yes
8B. The water rises
9. The body weight equals the water weight you displace

LESSON 16

1. No
2. No
3. No
4. No
5. Show buoyant (↑) forces on the floats
6. Water rises
7A. Yes
7B. It goes higher
8A. Either direction
8B. Air goes in the opposite direction
9A. Opposite the original direction
9B. Opposite direction from the boat
10A. Pushes the bat back
10B. Yes
11. Pushes your hand up
12. Push the rocket up
13. The recoil of a gun - bullet goes forward and the gun recoils

LESSON 17

1. Take actual measurement
2. By increasing the pump speed

LESSON 18

1. The pump forces the water jet backward - the water jet must force the boat forward
2. The boat still goes forward, but not so fast

LESSON 19

1. Yes
2. The water
3. No
4. The motor stalls
5. Lighter air is easier to push backwards. Less torque is needed
6. The air
7. Yes
8. Air weighs very little
9. Water
10. No

LESSON 19 - CONTINUED

11. Yes
12. Water
13. Yes
14. Yes
15. It shoots a great deal of heavy water at high speed
16. It requires more torque and more power to push heavy water at high speed

LESSON 20

1. Yes
2. Almost the same
3. Add another battery or gear up by replacing the speed reduction capsule with an internal gear capsule
4. The water
5. Boat barely moves
6. Boat goes in circles

LESSON 21

1. The large wheel
2A. Measure the actual force
2B. Measure the actual force (more force is needed for the small wheel)

LESSON 22

1. Once
2. It reduces friction
3. The worm gear capsule
4. Yes
5. The internal gearing looks like a worm
6. The speed reduction capsule delivers power in-line whereas the worm gear capsule delivers power on a 90 degree angle

LESSON 23

1. The blue clutch button allows you to change gears
2. No
3. Because gear 3 is larger than gear 2

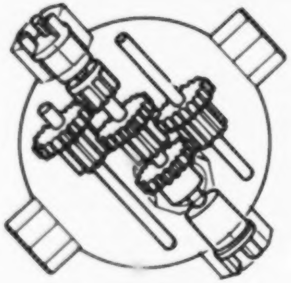
LESSON 24

1. Yes, but not well
2. The machine works best when the fan blades force the air out the rear exit
3A. Yes
3B. With a straw

LESSON 25

1A. Yes
1B. No
2. Yes
3. Yes
4A. Backwards
4B. Forward
5. Refer to teachers' notes

Capsela® Captain



NAME ______________________________

DATE ______________________________

SIGNED ______________________________

TEACHER'S RECORD PAGES

STUDENT LESSON	1	2	3	4	5
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STUDENT LESSON	6	7	8	9	10
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STUDENT LESSON	16	17	18	19	20
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TEACHER'S RECORD PAGES

STUDENT LESSON	21	22	23	24	25
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TEACHER'S RECORD PAGES

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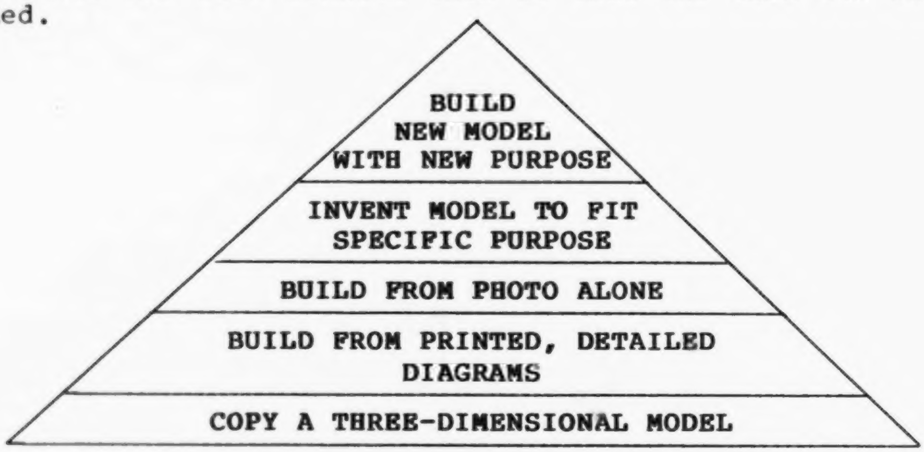
A WORD ABOUT THE CAPSELA OLYMPICS

As your children build with Capsela within the scope of your science curriculum, they will be referring to three-dimensional models which they are required to emulate, or they will have the help of a detailed construction diagram during their building activities.

In the Olympics, you will be graduating your children to more sophisticated levels of the visual-motor thinking processes. It is more difficult to create a three-dimensional representation of a figure seen only in a photograph. It is even harder to create an original model having only the function of the model in mind. The most difficult aspect of this "building hierarchy" is for the children to be given the names of several parts and asked to construct an original model, for in this case the children must conceive of a function for the components and also connect them so that the task can be performed.


BUILD NEW MODEL WITH NEW PURPOSE
INVENT MODEL TO FIT SPECIFIC PURPOSE
BUILD FROM PHOTO ALONE
BUILD FROM PRINTED, DETAILED DIAGRAMS
COPY A THREE-DIMENSIONAL MODEL

A LEARNING-THINKING HIERARCHY
FOR THE CAPSELA CURRICULUM PACKAGE

As challenging as the Olympic tasks may seem, this aspect of the Olympics is also the most exciting. It is within the Olympics that you will see intelligent creativity in action. Rather than the haphazard connection of pieces in random abandon, all activities within the Games have specific criteria that must be met.

Children like to think especially with their bodies and their eyes. In the Olympics, your students will be actively engaged in dynamic thinking activities. This is one of the reasons why they will have so much fun.

INTRODUCTION:

The Capsela Olympics is a motivational activity that focuses upon:

1. The children's knowledge of general science concepts explored in your classroom.

2. The specific features of the Capsela Scientific set itself.

You can use the Olympics in one of the following ways:

1. **A CUMULATIVE, END-OF-YEAR HIGHLIGHT ACTIVITY**
   After your students have done a fair amount of building in conjunction with their science curriculum, this activity will motivate your students at a time when school interest generally begins to wane.

2. **A SCIENCE ENERGIZER PRESENTED SEVERAL TIMES DURING THE YEAR**
   By simply modifying the questions and tasks to include only what you have covered up to any given point in the school year, you can hold these Olympics as often as you wish.

CAPSELA OLYMPICS: THIS ACTIVITY REINFORCES AND EXTENDS ALL CONCEPT AREAS

OVERVIEW

Your students will be able to apply the scientific principles they have covered in a competitive, yet friendly atmosphere. At the same time, you will be able to monitor how much they have learned without imposing a formal test on your students. In this way, the Games can be of direct assistance to you in your future lesson planning -- both with Capsela and with your science textbook.

PERFORMANCE OBJECTIVE

Specific tasks are detailed in the Olympic Manual. General categories include 1) the identification of the capsules and their functions, 2) the construction of Capsela models pictured in the design manual, and 3) a "freestyle" building activity that focuses upon your students' abilities to combine capsules and concepts in new and creative ways.

PERFORMANCE STANDARD

Each Olympic event is delimited by specific criteria, with points awarded for successful completion. See the Olympic Manual for details.

MATERIALS: CAPSELA SCIENTIFIC

Olympic Manual, Olympic Components Specified for Planned Event

TEACHERS' NOTES CAPSELA OLYMPICS: THIS ACTIVITY REINFORCES AND EXTENDS ALL CONCEPT AREAS

1. Show the "Capsela Cup" awards to the class.
2. Tell the class that they will compete in the Capsela Olympics.
3. Relate this activity to the Olympic events they have seen on T.V. Emphasize good sportsmanship, fair play, and team spirit.
4. Explain the procedures and the rules (see the Olympics Manual).
5. Choose your events and run them.
6. Record team scores.
7. Give out "Capsela Cup" awards.
8. Optional: Display winning models to the class. (Perhaps the winners would like to explain how their creations work.)
9. If you find that a specific concept area needs additional re-teaching, plan lessons that will close these knowledge gaps.

ROUND 1: DEFINITIONS/FUNCTIONS COMPETITION

DESCRIPTION

Each team lines up behind a starting line at one end of the room. A sports-related task will be performed by each member of every team, the tasks being presented in a relay race format. After each line of team players has moved to the finish line, the line winner will have the chance to answer a question on the identification of function of a Capsela component. During this round, one point will be awarded for each correct answer.

COMPETITIVE EVENTS

BALANCE THE CANDY ON THE SPOON

Use plastic spoons and wrapped candies. One line of children "race" at a time. If a candy falls, the child must stop where it fell, replace the candy, and continue from that point. The line winner answers the question; all racers get to eat the candy after they cross the finish line.

STANDING BROAD JUMP

One line of children jump as far as they can from behind the starting line. Distance is judged by where each child's feet first land. The line winner answers the question.

SACK OR PILLOW CASE RACE

Each line of children must amble from starting point to finishing point with both feet inside of a sack or pillow case. The line winner answers the Capsela question.

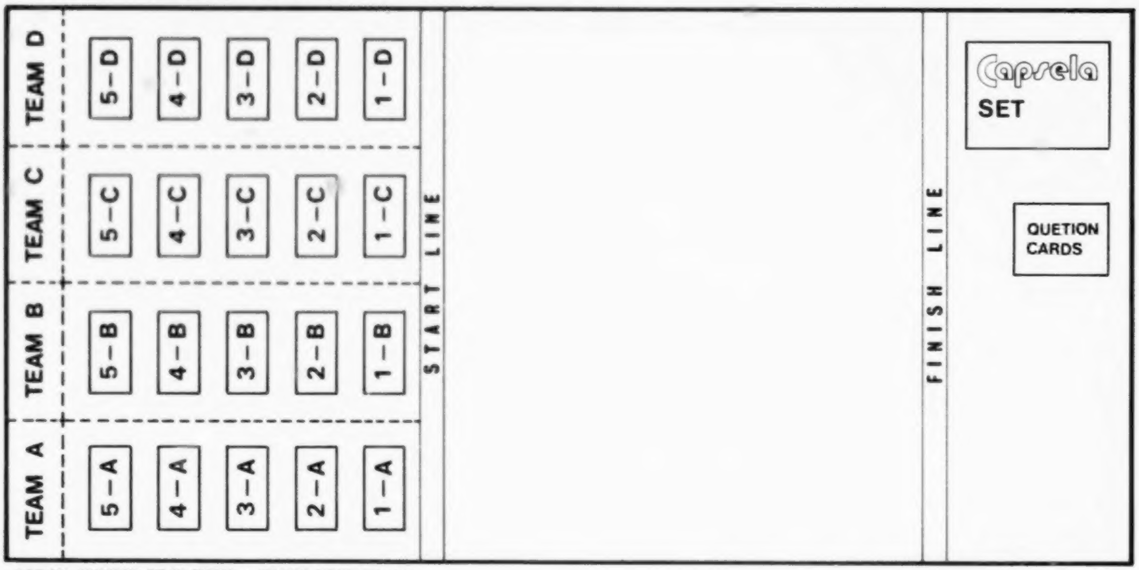
SCORING

Credit one point for each question answered and tally each point on the scoring sheet. A scoring grid on a blackboard will enable children to see their standings as they progress through the activities.

SET-UP

Line up your students in a manner similar to the diagram below. Have your Capsela set, scoring materials and the question cards ready behind the finish line. If you cannot even the team numbers, have some members of the smaller team go twice to even out the players.

IF YOUR STUDENTS WEAR NUMBERS, IT WILL BE EASIER TO LINE THEM UP AND SCORE RESULTS.


TEAM D
5-D
4-D
3-D
2-D
1-D
TEAM C
5-C
4-C
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2-C
1-C
TEAM B
5-B
4-B
3-B
2-B
1-B
TEAM A
5-A
4-A
3-A
2-A
1-A
START LINE
FINISH LINE
Capsela SET
QUETION CARDS

ACTUAL NUMBER OF PLAYERS + TEAMS DEPENDS ON YOUR CLASS SIZE. AIM FOR AN EVEN NUMBER OF STUDENTS ON EACH TEAM.

VARIATIONS

1. Make up your own questions to add to those included in this Olympic packet.

2. Substitute other team relay-type activities for the events presented here, or add on to the total number of competitive events. Other events to consider might include:

   a. Three-legged Race (the two winners can discuss their answers before replying)

   b. 50-Yard Dash (if you have the facilities)

   c. Hopping or Skipping Races

ROUND 2: CONSTRUCTION COMPETITION

DESCRIPTION

Each team will divide up into groups of 2, 3, or 4 sub-teams. Each sub-team will have to build one of the Capsela models pictured in the design manual within a maximum of 20 minutes.

COMPETITIVE EVENTS

Assign one of the following models to be built by each competing sub-group. Each group builds the same model until all team participants have had the chance to compete. If you wish, you can repeat this event as many times as you want within this round of the competition, assigning a different model to be built each new time.

CONSTRUCT THE FOLLOWING MODELS

The Bulldozer	(page 11 in Design Manual)
The Speed Boat	(page 11 in Design Manual)
The Tractor	(page 17 in Design Manual)
The Elevator	(page 18 in Design Manual)
The Tank	(page 21 in Design Manual)

SCORING

Models are judged on the basis of accuracy and function. 5 points are awarded if the model looks like the picture in the design manual. 5 points are awarded if the model runs when the power is turned on.

SET UP

Rotate your students through the building competition as you would through the Capsela Learning Centers. Pay strict attention to time limits, and establish the rule that the children at the building task can communicate with each other, but with no one else, while they engage in this building task.

VARIATIONS

The models listed above are only suggestions. You may choose any models pictured in the design manual. Lengthen or shorten the suggested building time to accommodate the needs of your class.

ROUND 3: FREESTYLE

DESCRIPTION

Each team sub-group (use the same divisions as in Round 2) will have a maximum of 25 minutes to construct a creative Capsela model using one of the following guidelines:

1. The building team will be given a list of Capsela parts that must be used in the construction of the model

or

2. The building team will be given a function to be performed by the completed model.

COMPETITIVE EVENTS

Choose the guidelines of your freestyle competition: Will you give your students a list of parts to be used, or would you rather give them a function to be fulfilled by their completed structure? Then, refer to the list of suggested building frameworks to assign a construction task to your students. Each sub-group will work under the same guidelines until all team participants have had the chance to compete. If you wish, you can repeat this event as many times as you want within this competition round, assigning different guidelines and/or different criteria to be met each new time.

SCORING

Models are judged on the basis of accuracy and function.

If a list of parts was given:
Score 1 point for each correct part used. Score 5 points if the model runs.

If a function was given:
Score 10 points if the model runs and performs the pre-stated function. Score 5 points if the model runs but does not fulfill the required function. If the model does not run, there is no score.

SET-UP

Rotate your students through this freestyle as you did in Round 2. Pay strict attention to time limits, and enforce the rule that the children at the building task can communicate with each other, but with no one else, while they engage in this building task. The use of the design manual during this activity is up to you -- it makes the task easier for the children. But remember to make the design manual available for all sub-groups if you wish to incorporate the catalog in this task.

VARIATIONS

The tasks below are only suggestions. You can make up your own list of parts to be used, or think of a different function you would like the finished model to perform. The suggested 25-minute building time can be altered to fit your students' needs.

ROUND 3 FREESTYLE EVENTS

Building From A List of Parts

Build a Capsela model including the following parts:
Motor Capsule
Speed Reduction Capsule
Crown Wheel Capsule
4 Large Wheels
Switch Box

Build a Capsela model including the following parts:
Motor Capsule
1 Impeller
4 Floats

Build a Capsela model including the following parts:
Motor Capsule
2 Gear Wheels
1 Chain
Worm Gear Capsule

Building A Model To Perform A Given Function

Design a model that blinks as it rolls on its wheels.
Design a model that turns round and round.
Design a model that uses the pushing power of water to make it move along the water's surface.

1. Cut out the cards. 2. Laminate them if you wish. 3. Shuffle the cards before each use. 4. Place the cards face down.	FIND THE WINDING DRUM	THIS WHEEL ATTACHES TO THE CHAIN	THIS CASE PROVIDES DOUBLE THE POWER
FIND THE CLEAR CAPSULE	FIND THE SPEED REDUCTION CAPSULE	FIND THE LARGE BATTERY CASE	FIND THE PUMP
FIND THE GEAR WHEEL	FIND THE INTERNAL GEAR CAPSULE	FIND THE CHAIN	FIND THE SWITCH BOX
THIS CAPSULE CAN MAKE A WHEEL TURN ROUND AND ROUND	FIND THE WORM GEAR CAPSULE	THIS CAPSULE MAKES THE LAMP BLINK	THIS CAPSULE CAN MAKE A MODEL GO BOTH FORWARD AND REVERSE

FIND THE FAN	FIND THE COUPLER	FIND THE AXLE SUPPORT	THIS CONNECTS A BATTERY CASE WITH THE MOTOR
FIND THE MOTOR CAPSULE	FIND THE FREE COUPLER	FIND THE SHORT AXLE	FIND THE TRIANGULAR WHEEL
FIND THE TRANSMISSION CAPSULE	FIND THE COUPLER CAP	THIS LIGHTS UP YOUR MODEL	FIND THE SMALL WHEEL
FIND THE SMALL BAR CONNECTOR	FIND THE OCTAGONAL CONNECTOR	FIND THE PROPELLER	FIND THE SMALL BATTERY CASE

OLYMPIC SCORING RECORD

	TEAM A	TEAM B	TEAM C	TEAM D	TEAM E	TEAM F
ROUND 1						
Total						
ROUND 2						
Total						
ROUND 3						
Total						
TOTALS						
FINAL STANDING						

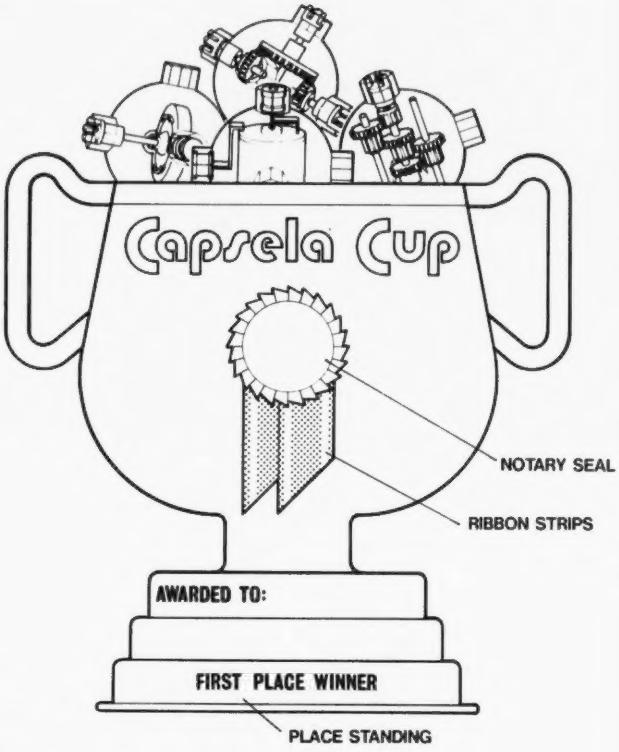
Sample Scoring Record

1 POINT SCORED FOR CORRECT EACH ANSWER

2 DIFFERENT MODELS WERE BUILT

1 MODEL WAS BUILT

	Olympic Scoring Record					
	TEAM A	TEAM B	TEAM C	TEAM D	TEAM E	TEAM F
ROUND 1	III	II	IIII	~~IIII~~		
	③	②	④	⑤		
ROUND 2	10 10	5 5	5 5	10 5		
	⑳	⑩	⑩	⑮		
ROUND 3	10	15	15	10		
	⑩	⑮	⑮	⑩		
TOTALS	33	27	29	30		
FINAL STANDINGS	1ST	4TH	3RD	2ND		

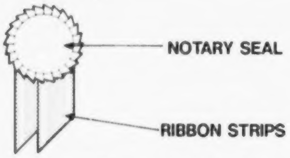

Capsela Cup
NOTARY SEAL
RIBBON STRIPS
AWARDED TO:
FIRST PLACE WINNER
PLACE STANDING

EVERYONE SHOULD RECEIVE A

CAPSELA CUP

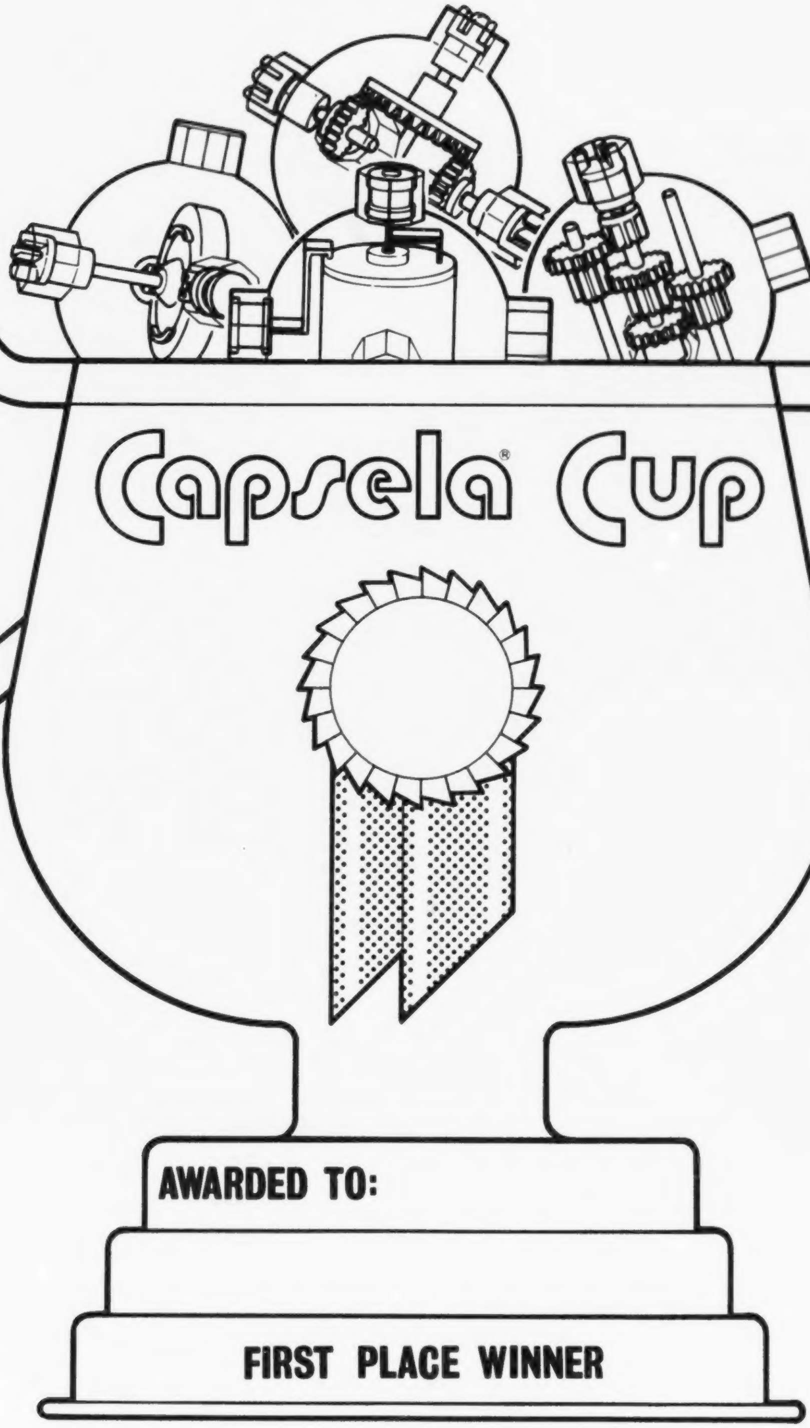
a) Label the bottom of the cups according to place standings.

b) Use gold notary seals and different strips of ribbon (3"); attach a ribbon in the center of each cup.


NOTARY SEAL
RIBBON STRIPS

c) Let the ribbon color designate Place standings:

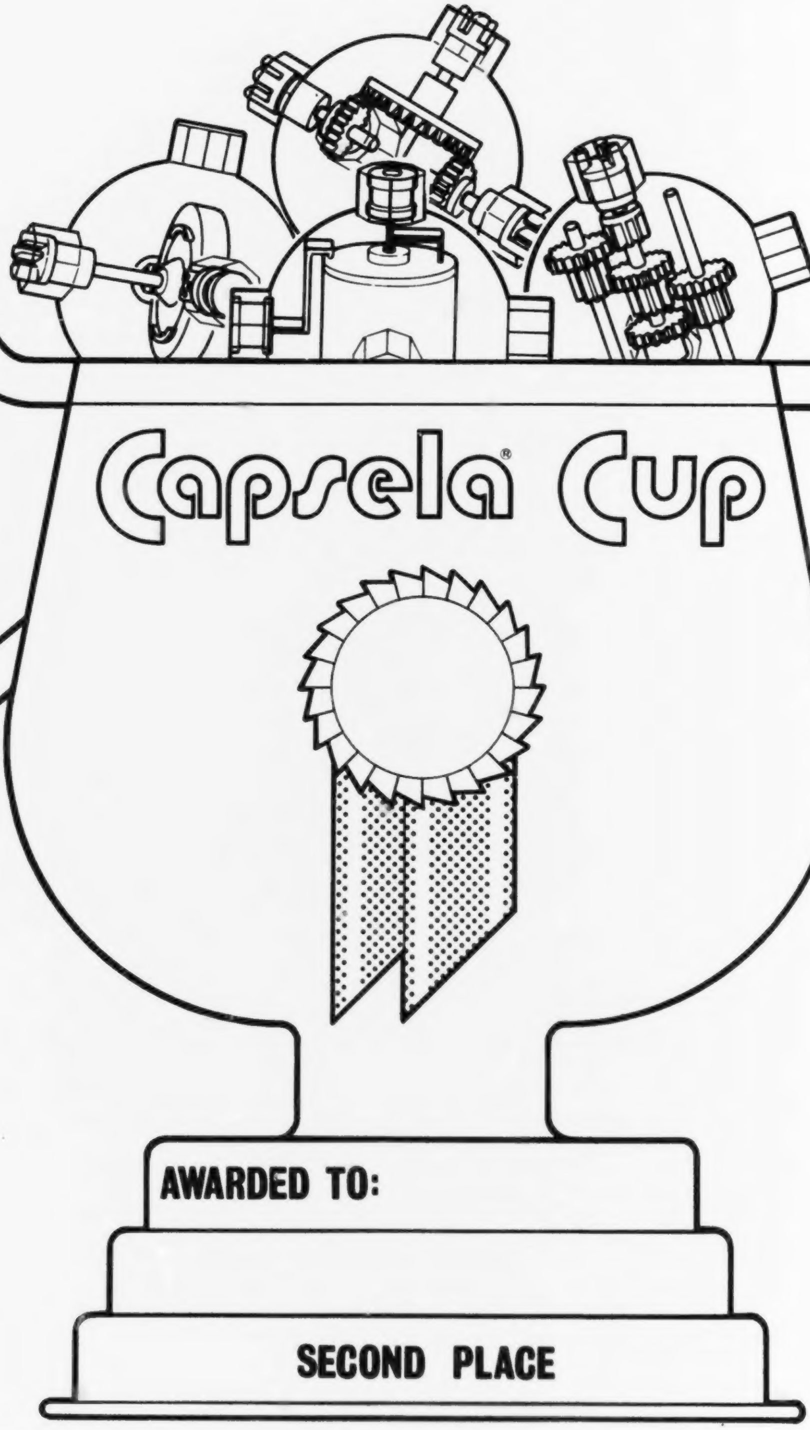
1st GOLD
2nd SILVER
3rd BLUE
4th GREEN
1st HON. MENTION RED.
2nd HON. MENTION YELLOW.



Capsela® Cup

AWARDED TO:

FIRST PLACE WINNER


Capsela® Cup

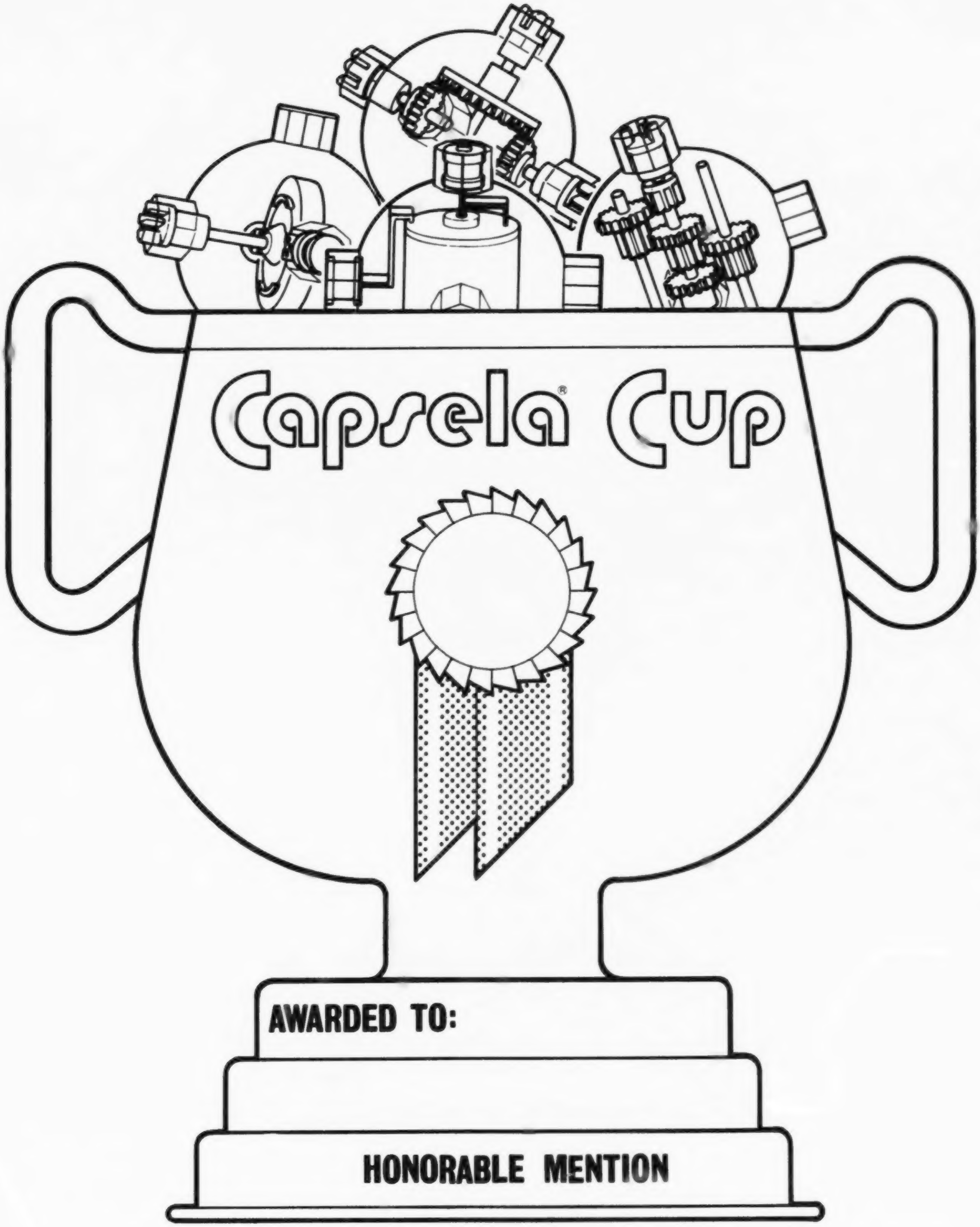
AWARDED TO:

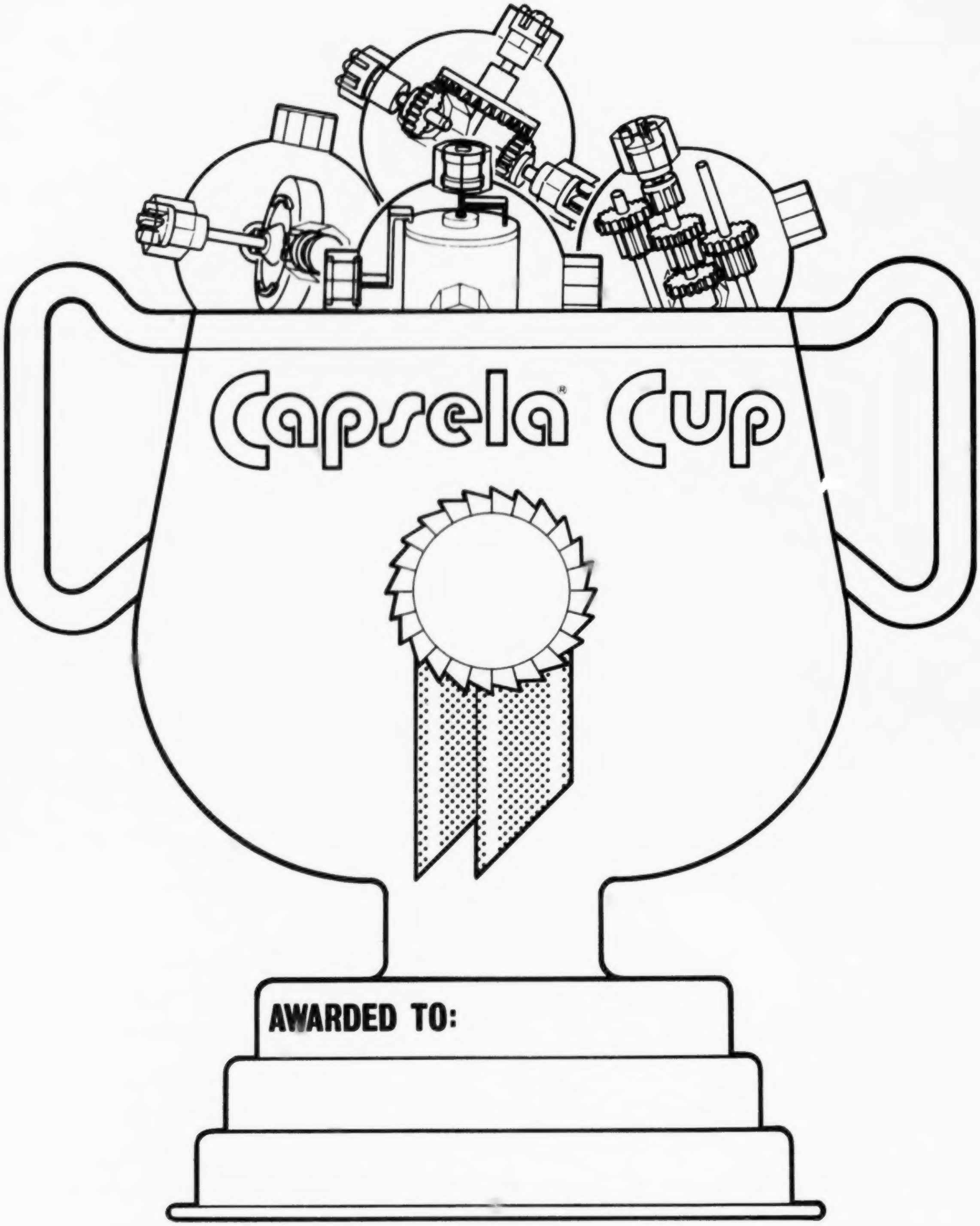
SECOND PLACE

Capsela® Cup

AWARDED TO:

THIRD PLACE


Capsela® Cup
AWARDED TO:
HONORABLE MENTION


Capsela® Cup
AWARDED TO:

CAPSELA WORD SEARCH: VOCABULARY REVIEW

OVERVIEW
Here is a brief review of vocabulary that can be presented in several different ways.

PERFORMANCE OBJECTIVE

Each underlined word in the Word List is hidden within the capsule-shaped puzzle. Your students will find each word and draw an oval around it. The words have been arranged in both horizontal (right-to-left and left-to-right) and vertical (up-down and down-up) directions.

PERFORMANCE STANDARD

All 16 words must be found. Please note that "axle" appears only once.

MATERIALS: CAPSELA SCIENTIFIC

Capsela Word Search Student Hand-out Sheet

TEACHERS' NOTES: CAPSELA WORD SEARCH: VOCABULARY REVIEW

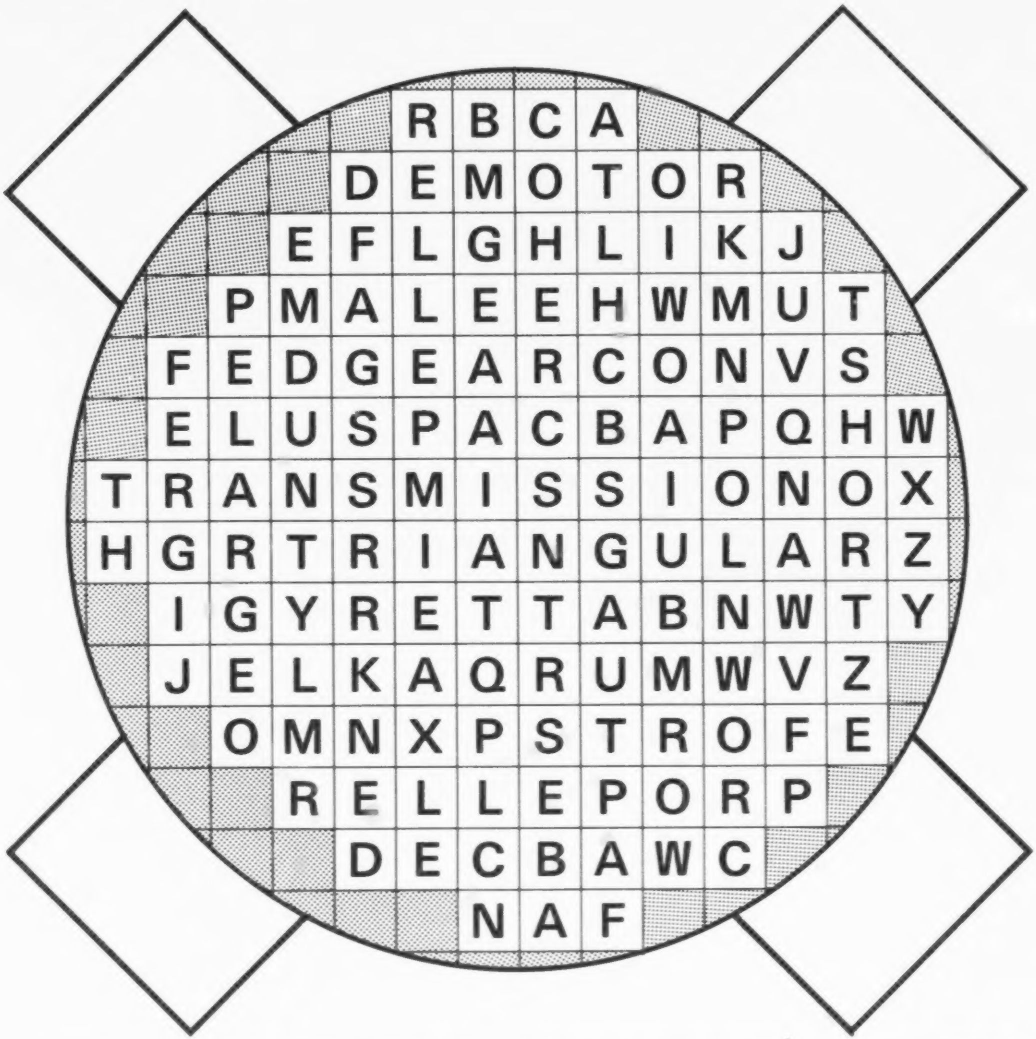
OPTIONAL MODES OF PRESENTATION

1. Set up a Capsela Center where your students can rotate through this activity.
2. Offer the word search as a full-class activity.
3. Assign the word search for homework.

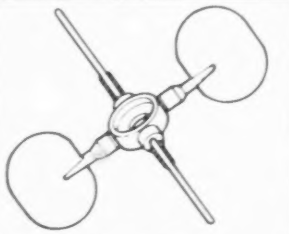
ASSESS PERFORMANCE

RECORD STUDENT PROGRESS

STUDENT HAND-OUT SHEET
WORD SEARCH PUZZLE



R B C A
D E M O T O R
E F L G H L I K J
P M A L E E H W M U T
F E D G E A R C O N V S
E L U S P A C B A P Q H W
T R A N S M I S S I O N O X
H G R T R I A N G U L A R Z
I G Y R E T T A B N W T Y
J E L K A Q R U M W V Z
O M N X P S T R O F E
R E L L E P O R P
D E C B A W C
N A F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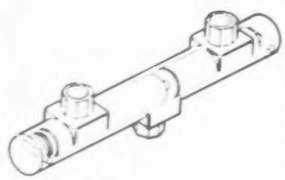
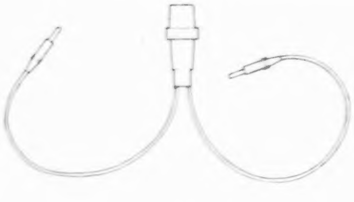

LARGE BATTERY CASE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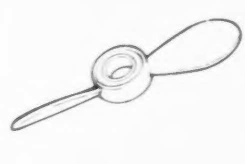
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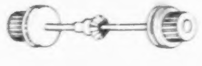
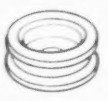
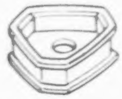
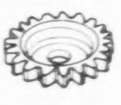
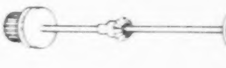
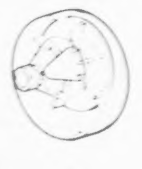

SHORT AXLE

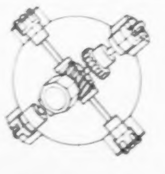

SMALL WHEEL

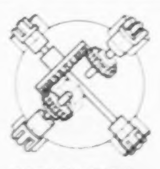

TRIANGULAR WHEEL

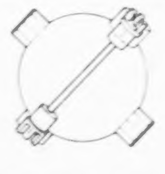

GEAR WHEEL

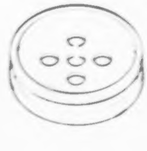

AXLE

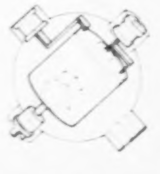

FAN


WORM GEAR CAPSULE

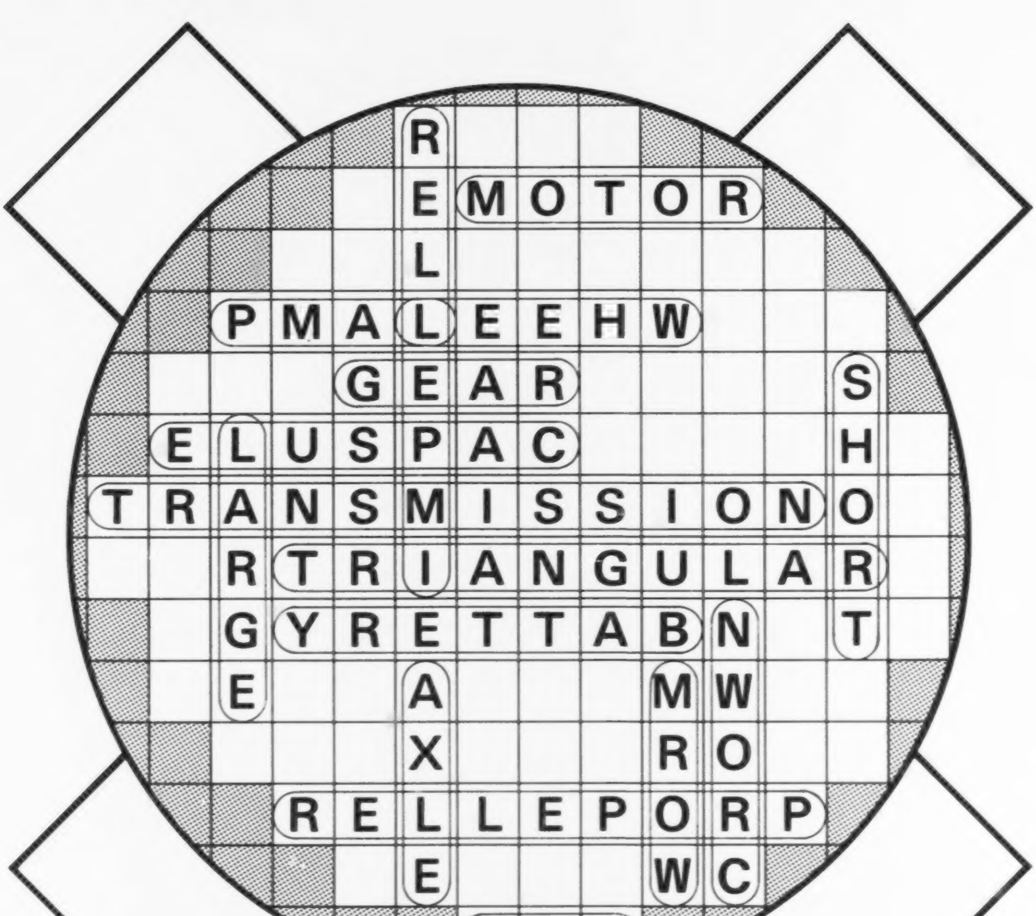

CROWN WHEEL CAPSULE


TRANSMISSION CAPSULE

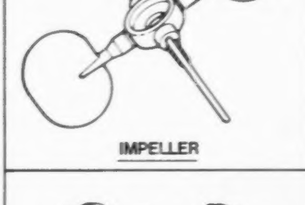

LARGE WHEEL


MOTOR CAPSULE

WORD SEARCH ANSWERS



					R								
					E	M	O	T	O	R			
					L								
		P	M	A	L	E	E	H	W				
				G	E	A	R					S	
	E	L	U	S	P	A	C					H	
T	R	A	N	S	M	I	S	S	I	O	N	O	
		R	T	R	I	A	N	G	U	L	A	R	
		G	Y	R	E	T	T	A	B	N		T	
		E			A				M	W			
					X				R	O			
			R	E	L	L	E	P	O	R	P		
					E				W	C			
						N	A	F					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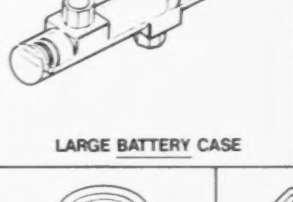
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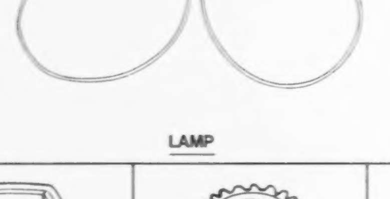
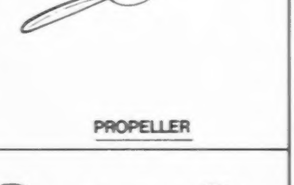

LAMP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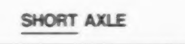
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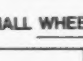
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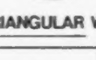
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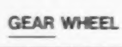
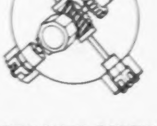

GEAR WHEEL

AXLE

FAN


WORM GEAR CAPSULE

CROWN WHEEL CAPSULE

TRANSMISSION CAPSULE

LARGE WHEEL

MOTOR CAPSULE

CAPSELA CROSSWORD PUZZLE: REVIEW OF CAPSULES, GEAR FUNCTIONS, AND SCIENTIFIC PRINCIPLES

OVERVIEW

This activity will focus upon the names of specific Capsela parts, the function of individual Capsela components, and some of the major scientific principles that are used during construction activities. It will give your students a chance to apply their research skills as they solve the puzzle, and you will be able to observe whether a basic science concept area might be in need of review.

PERFORMANCE OBJECTIVE

Every student will write, in the proper spaces provided on the puzzle, the word that answers each of the 17 crossword questions. The students can refer to the Capsela design manual and to their science textbooks and notes while they solve the puzzle.

PERFORMANCE STANDARD

Each of the 17 crossword answers will be correctly written in the spaces provided on the puzzle.

MATERIALS: Capsela Design Manual

TEACHERS' NOTES: CAPSELA CROSSWORD: REVIEW OF CAPSULES, GEAR FUNCTIONS AND SCIENTIFIC PRINCIPLES

WHOLE CLASS

1. Set up a Capsela Crossword Center and display it to the class.

2. Introduce the Center and explain how the components are to be used.

CENTER ACTIVITY

1. Rotate your students through the activity in 1 of the following ways:

   a) Individually
   b) Two At A Time
   c) In a Small "Research" Group of 3 or 4

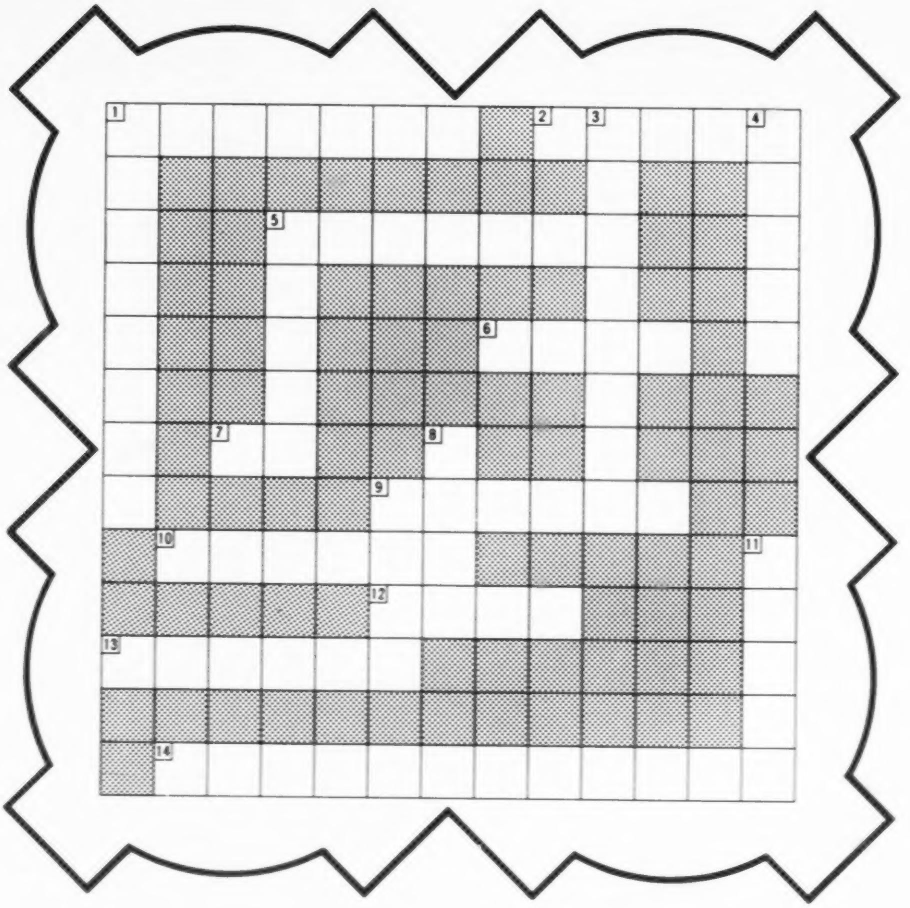
2. Assess performance and record student progress.

WHOLE CLASS

1. Review the correct answers and detail any areas that seemed difficult for the children to answer. Show how the answers could have been found using the reseach materials, or describe how the childen could have deduced the correct word from puzzle clues.

2. Re-present concepts that indicate a need for further review.

STUDENT HAND-OUT SHEET:
CAPSELA CROSSWORD PUZZLE

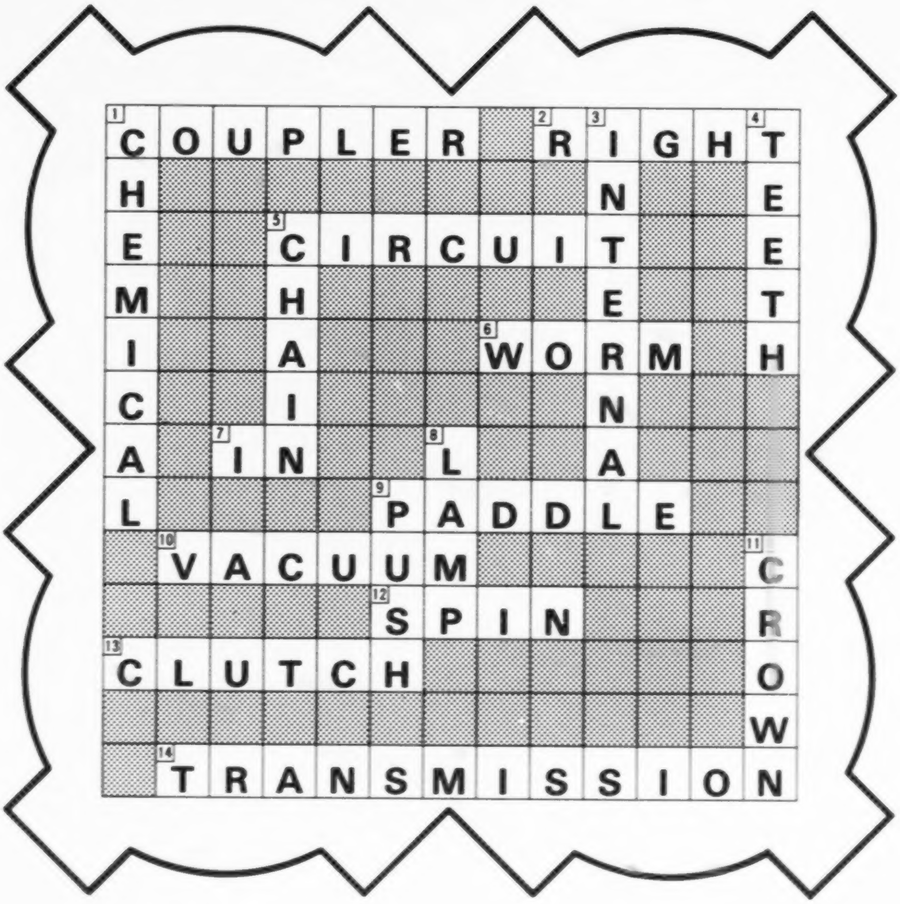


ACROSS

1. Use the ____________ to connect the propeller to the motor.
2. The Worm Gear Capsule slows down the speed of a model when the drive axle is connected at a __________ angle to the worm gear.
5. Electricity flows through a path called a ________________.
6. You would not use this gear capsule for fishing, even though it sounds like you could.
7. Connect the battery to the ______ part of the Switch Box.
9. The impeller acts as the ____________ wheel on a riverboat to push it through the water.
10. When the fan spins around, air rushing out rushing out of a partly-sealed compartment creates a partial ________________.
12. The Crown Wheel Capsule can be used to make your model ______________ round and
13. Use the __________ Capsule to change your model's direction without using the switch box.
14. This capsule extends the action of any gear without changing anything else.

DOWN

1. Three kinds of energy are ELECTRICAL, MECHANICAL, and ________________.
3. Use the ____________ Gear Capsule to change the speed of your model when you don't want to change the direction of the drive force.
4. Gears are wheels with ______________.
5. This connects two gear wheels so that they can turn together.
8. This part adds light to your models.
9. Force is a ______________ or a pull.
10. This capsule gets its name from the hat worn by kings and queens.



1 C	O	U	P	L	E	R		2 R	3 I	G	H	4 T
H									N			E
E			5 C	I	R	C	U	I	T			E
M			H						E			T
I			A				6 W	O	R	M		H
C			I						N			
A		7 I	N			8 L			A			
L					9 P	A	D	D	L	E		
	10 V	A	C	U	U	M						11 C
					12 S	P	I	N				R
13 C	L	U	T	C	H							O
												W
	14 T	R	A	N	S	M	I	S	S	I	O	N

ACROSS

1. Use the **coupler** to connect the propeller to the motor.
2. The Worm Gear Capsule slows down the speed of a model when the drive axle is connected at a **right** angle to the worm gear.
5. Electricity flows through a path called a **circuit.**
6. You would not use this gear capsule for fishing, even though it sounds like you could. **Worm**
7. Connect the battery to the **in** part of the Switch Box.
9. The impeller acts as the **paddle** wheel on a riverboat to push it through the water.
10. When the fan spins around, air rushing out of a partly-sealed compartment creates a partial **vacuum.**
12. The Crown Wheel Capsule can be used to make your model **spin** round and
13. Use the **Clutch** Capsule to change your model's direction without using the switch box.
14. This capsule extends the action of any gear without changing anything else. **Transmission**

DOWN

1. Three kinds of energy are ELECTRICAL, MECHANICAL, and **CHEMICAL.**
3. Use the **internal** Gear Capsule to change the speed of your model when you don't want to change the direction of the drive force.
4. Gears are wheels with **teeth.**
5. This connects two gear wheels so that they can turn together. **Chain**
8. This part adds light to your models. **Lamp**
9. Force is a **push** or a pull.
10. This capsule gets its name from the hat worn by kings and queens. **Crown**

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Dr. Clifford E. Swartz: Univ. of Rochester AB, MS, PhD. Phi Beta Kappa, Professor of Physics at State Univ. of New York at Stony Brook. Editor of The Physics Teacher, 1967-1985. Author of over two dozen books ranging from elementary school science texts to a graduate level text on sub-atomic physics. Winner of numerous awards including the Westinghouse Science Talent Search Scholarship, the Oustanding Civilian Service Medal of the Department of the Army, and the 1986 Oersted Medal of the American Association of Physics Teachers.

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